ABSTRACT

PRINCIPLES FOR DESIGNING AND CONDUCTING LEARNING EXPERIENCES FOR IMPROVING PROBLEM-SOLVING ABILITIES AS APPLIED TO INDUSTRIAL ARTS TEACHING

By George William Ferns

The primary purpose was to develop principles for guiding industrial arts teachers when designing and conducting learning experiences for improving student problem-solving abilities. The findings, however, were equally valuable for teachers of other subjects.

Research Method

The principles were developed as the result of careful examination of (1) writings of selected authorities in education who have dealt with problem solving as an objective and method of education, (2) the writings of educational philosophers John Dewey and William Kilpatrick, and (3) experimental research studies in problem solving. This study is best classified as philosophical. It may also be identified as synthetic research since its purpose was to focus on a central problem the concepts and findings originating in a number of studies.

Procedure

In Chapter I, the purpose of the study was identified,

ABSTRACT

PRINCIPLES FOR DESIGNING AND CONDUCTING LEARNING EXPERIENCES FOR IMPROVING PROBLEM-SOLVING ABILITIES AS APPLIED TO INDUSTRIAL ARTS TEACHING

By George William Ferns

The primary purpose was to develop principles for guiding industrial arts teachers when designing and conducting learning experiences for improving student problem-solving abilities. The findings, however, were equally valuable for teachers of other subjects.

Research Method

The principles were developed as the result of careful examination of (1) writings of selected authorities in education who have dealt with problem solving as an objective and method of education, (2) the writings of educational philosophers John Dewey and William Kilpatrick, and (3) experimental research studies in problem solving. This study is best classified as philosophical. It may also be identified as synthetic research since its purpose was to focus on a central problem the concepts and findings originating in a number of studies.

Procedure

In Chapter I, the purpose of the study was identified,

the method of research explained, and the problem-solving situation defined. The theoretical base for problem solving as an instructional objective was described in Chapter II. In addition, a system for deriving educational goals was investigated. The roots of problem solving as an objective were examined, and a broad statement of the objective was translated into a series of definitive phrases descriptive of desired behavioral outcomes. A rationale was then developed for the contribution of industrial arts instruction to this goal.

In Chapter III, problem solving was treated as a method of teaching and learning. The method was described and its strengths cited. Emphasis was given to the inseparability of objective and method. The conditions of educative experience were then developed as a base for identifying more specific principles.

In Chapter IV, the writings of John Dewey and William Kilpatrick were examined to locate philosophical concepts which resulted in the listing of a number of principles. Reports and summaries of experimental research were examined in Chapter V to isolate germane principles.

Both sets of principles evolving out of the investigation of the two sources were merged in Chapter VI. These were organized around Dewey's phases of reflective thinking; plus a category for principles too general and broad for inclusion in any one of the five phases. The resulting principles were then applied to the teaching of industrial arts in Chapter VII. Representative teaching-learning situations were described in some detail; and emphasis was given to showing the application of the principles. The study was summarized in Chapter VIII.

Principles Developed

The following underlying principles were developed and sustained by rational and authoritative means:

1. The greatest gains in improving student problem-solving abilities can be affected when the teacher consciously plans learning experiences with the goal of improving problem-solving ability in mind.

2. The improvement of student problem-solving abilities is best accomplished by the teacher's regulating indirectly the conditions which guide it.

3. The exposure of students to direct experience in attempting to solve real-life problems through the use of problem-solving method is the teacher's most appropriate way to achieve improvement in problem-solving abilities.

4. In designing and selecting problem situations suitable for improving student problem-solving abilities, it is important that the teacher make the distinction between genuine problems and those which are not. The following

criteria serve to define authentic problem situations.

a. There should be an objective in view.

b. There should be something blocking the objective.

c. There should be awareness or consciousness of the goal and blocking obstacle. There should be intellectual activity.

d. There should be a high degree of subjective identification or motivation.

e. Problem situations at both ends of a problem difficulty continuum, which range from the extremes of the completely familiar (rectifiable through unthinking, habitual response) to puzzles (solvable through accident, rational means being of little consequence), are less desirable problem situations than those in between and should be minimized.

5. It should be recognized that problem solving is both a method and an objective in education. It is a means for achieving numerous educational objectives, including improvement of problem-solving abilities. It is also an end or an objective of education because of its significance as a method in living and learning.

6. Problem-solving method is practically synonymous with learning; and there are indications that problem solving is generally equal or superior to other methods of learning.

7. Learning experiences, to be educative, should provide for further growth, for interaction between individual and environment, and for intelligent managing of ends and means. They should be continuous with past and future experience, should have both active and passive elements, and should include reflective thinking.

These were followed with over seventy principles, more specific than those above, which were concerned with methods, techniques, and devices for guiding teachers when designing and conducting learning experiences for improving student problem-solving abilities. They were organized under the five phases of problem-solving method, plus a category named General Considerations.

PRINCIPLES FOR DESIGNING AND CONDUCTING LEARNING EXPERIENCES FOR IMPROVING PROBLEM-SOLVING ABILITIES AS APPLIED TO INDUSTRIAL ARTS TEACHING

by

GEORGE WILLIAM FERNS

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

College of Education

1962

ACKNOWLEDGMENTS

The writer is indebted to several individuals for their contributions in helping to make this study a reality. He is particularly appreciative of the guidance of Professor Lawrence Borosage, who as chairman of the writer's doctoral guidance committee, was most generous with his time and counsel. Other guidance committee members who also gave liberally of their time were: Professors John A. Fuzak, Industrial Education; Carl H. Gross and John W. Hanson, Social Historical and Philosophical Foundations of Education; John M. Mason, Science Education; John F. A. Taylor, Philosophy. The author is especially grateful for their encouragement to undertake and complete an unusual, challenging, and educative research problem.

Further appreciation is expressed to the author's immediate colleagues, Professors George L. Brandon and C. Blair MacLean for the many ways in which they helped bring this study to its realization.

Greatly appreciated were the efforts of the writer's wife, Laura, for her ready encouragement, untiring assistance with the manuscript, and willingness to assume the major share of effort and responsibility for raising and providing home life for three young children during the time that this study was underway.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	iii
Chapter	
I. NATURE OF THE STUDY	1
Purpose of the Study	1
Background of the Problem	2
Assumptions	6
Delimitation	7
Definition of the Problem-Solving Situation	9
Problem Solving As Method and As Objective	16
Industrial Arts Defined	17
Research Method	17
Preview of Succeeding Chapters	19
Bibliography	22
II. PROBLEM SOLVING AS A GOAL OF EDUCATION	23
Basis for Derivation of Educational Goals .	23
Ability in Problem Solving Needed to Help Cope with Change	25
Problem-Solving Ability, the Keystone of Democracy	28
Dewey's Reasons for Reflective Thinking as an Aim of Education	32
Learning Depends on Reflective Thinking . .	33
Validating the Problem-Solving Objective .	34
Improvement of Problem-Solving Abilities Will be Facilitated Through Conscious Planning by Teachers	35
Problem Solving Defined Behaviorally . . .	36
Contribution of Industrial Arts to the Improvement of Problem-Solving Abilities .	44
Summary	48
Bibliography	50
III. PROBLEM SOLVING AS METHOD OF EDUCATION . . .	53
Problem-Solving Method Described	53

Chapter		Page
	Relationship of Objectives and Methods . .	59
	Relationship of Subject Matter and Problem-Solving Method	62
	Distinction Between Method and Technique .	64
	Strengths of Problem-Solving Method . . .	64
	Conditions of Educative Experience	72
	Summary	80
	Bibliography	82
IV.	PRINCIPLES FOR IMPROVING PROBLEM-SOLVING ABILITIES FROM PHILOSOPHERS DEWEY AND KILPATRICK	85
	Development of Problem-Solving Abilities is Indirect	86
	Source and Nature of Problems	89
	Problem Definition	103
	Occurrence of Suggestions for Development into Problem Solutions	108
	Development of Hypotheses by Reasoning . .	117
	Testing of Hypotheses by Experimentation .	123
	General Considerations	127
	Summary	137
	Bibliography	147
V.	PRINCIPLES FOR IMPROVING PROBLEM-SOLVING ABILITIES FROM EXPERIMENTAL RESEARCH . . .	148
	Preparation	151
	Production	155
	Verification	158
	General Considerations	159
	Summary	177
	Bibliography	184
VI.	PRINCIPLES FOR DESIGNING AND CONDUCTING LEARNING EXPERIENCES FOR IMPROVING PROBLEM-SOLVING ABILITIES	188
	Need for Guiding Principles	188
	Principles Defined and Described	189
	Using Principles Developed in This Study .	192
	Principles Underlying the Improvement of Problem-Solving Abilities	194
	Principles for Designing and Conducting Learning Experiences for Improving Problem-Solving Abilities	197
	Bigliography	211

Chapter		Page
VII.	APPLICATION OF PRINCIPLES TO INDUSTRIAL ARTS TEACHING	212
	Problem in Selection of a Plan	212
	Problem in Social Living	215
	Problem in Tool Process Selection	218
	Problem in Materials Selection	223
	Problem in Quantity Production	225
	Problem in Designing a Holding Fixture . .	228
	Summary	230
VIII.	SUMMARY	231
	Purpose and Procedure	231
	Conclusions	233
	Additional Research	237
APPENDICES		
A.	HISTORICAL REVIEW OF THE LITERATURE OF INDUSTRIAL ARTS TO DETERMINE CONCERN FOR PROBLEM SOLVING AS A GOAL AND METHOD OF INSTRUCTION	239
	Decade, 1930-1940	240
	Decade, 1941-1950	250
	Decade, 1951-1960	255
	Overview of Industrial Arts Concern for Problem Solving Based Upon Survey of the Literature--1930-1960	273
B.	PROBLEM-SOLVING OBJECTIVE DEFINED BEHAVIORALLY	282
C.	ATTITUDES FAVORABLE TO PROBLEM SOLVING . . .	284

CHAPTER I

NATURE OF THE STUDY

Purpose of the Study

If increasing student problem-solving ability is accepted as an educational goal, the teacher is faced with the task of designing and conducting learning experiences which will serve as means or vehicles. He can be viewed as an architect, a designer, or a planner of learning experiences. It is his responsibility to offer the most effective and efficient means possible for the achievement of goals by drawing from the reservoir of knowledge supplied by philosophy, experimental research, and experience. To assume such an obligation, teachers and teacher educators alike have need for guiding principles worked out through study of available information relative to their aim.

The primary purpose of this study is to develop principles for guiding industrial arts teachers when designing and conducting learning experiences which will improve student problem-solving abilities. The principles will be developed as the result of careful examination of (1) writings of selected authorities in education who have dealt with problem solving as an objective and method education, (2) the writings of educational philosophers John Dewey and

William Kilpatrick, and (3) experimental research studies in problem solving. With reference to the last two elements, a more efficient set of principles can result from studying the contributions of both sources, rather than concentration on only one, because they reinforce each other. Philosophy gives over-all orientation and direction to operational procedures; experimental research furnishes tested evidence regarding the effectiveness of the procedures. This study attempts to distill the information available in philosophical and experimental research, and to draw it together to form principles for improving problem-solving abilities. These principles then will be applied to industrial arts teaching.

This study also proposes to clarify the relationship of problem solving as an objective, to problem solving as a means of learning. It will give a rationale for problem solving as both an objective and a means in industrial arts instruction.

It is hoped this study will be of value to teachers of industrial arts as they seek to clarify and improve their contributions to the education of the nation's youth. Because the concepts and principles developed should have a degree of universality, they should be of value to teachers of other subjects who are interested in improving student problem-solving abilities.

Background of the Problem

Within the past ten years, the leadership of industrial arts teacher education has become increasingly concerned about improving student problem-solving abilities.[1] In preceding decades, although a few industrial arts persons were concerned about this educational goal, their voices had little impact upon practice. Many industrial arts teachers were thoroughly engrossed in developing improved methods of getting across tool operations and related information. They were oriented toward teaching of content drawn from trade and job analysis. A quickening of interest in problem solving during the past ten years is evidenced by the number of papers presented at professional meetings, articles published in journals, and by the beginnings of research in the area. Leaders have urged the channelling of attention in this direction.

Much has been said to form a philosophical basis for the inclusion of a problem-solving approach in industrial arts instruction; but little work has been carried on to show the teacher how he can teach in order to accomplish the objective of improved problem-solving ability. Little light has been shed on the theoretical issues involved in developing learning experiences favorable to the accomplishment of the objective. In general, industrial arts leadership is now aware of the appropriateness of the objective;

---

[1]See Appendix A: A review of the literature of industrial arts which indicates the growing concern regarding problem solving.

but has done little to advance knowledge of its achievement.

Industrial arts teachers in the field are far from agreement in their attitudes toward problem solving as an educational goal. They consider its inclusion in their programs with a variety of points of view ranging from dedicated interest, through lack of awareness, to the extreme of genuine hostility.

Among teachers accepting problem-solving ability as a goal are those who believe it to be a concomitant one achieved indirectly while they are pursuing other objectives. Others argue that it must be planned for directly if any significant achievement is to result. Those holding the latter position differ in their concepts of the methods and techniques that should be employed.

Some teachers doubt that problem solving can be accomplished in industrial arts classes unless students have a prior background of experience including basic information and skills. Some hold that students need a series of directed learning experiences in the basic processes of material fabrication before their background is adequate for solving problems. Another group believes the problem-solving situation should furnish a context in which processes can be learned as needed.

There is additional confusion as to whether problem solving is a method of learning, an objective of instruction, or both. Several points of difference within the industrial arts group warrant attention. If industrial arts teachers accept (1) improvement of problem-solving ability as a worthy objective, and (2) experience in problem solving as the method of learning most appropriate for its achievement, there is yet need for development of principles relative to designing and conducting learning experiences, and effective procedures for evaluating results. Since industrial arts educators have done little research in this direction, there is need for an investigation such as the one attempted in this study.

There is ample evidence that problem-solving ability has been a concern of general education for several decades. It has appeared on many lists of educational goals and in the literature of general education. As the complexities of contemporary living have multiplied, and as the pace of change has increased, the demand for intelligent, objective problem solving has surged upward. Ability in problem solving has become a social and personal imperative.

The education profession is in general agreement as to the value and importance of this objective. Teachers, however, are not in agreement as to how to implement the goal. It is hypothesized in this study that a careful examination of the works of Dewey and Kilpatrick, and of experimental researchers, can lead to formulation of principles pertaining to the teaching of this objective.

Education traditionally focuses the research findings of other disciplines on problems of the educative process. Research in philosophy and psychology are particularly pertinent to the understanding of problem solving as a concern of education. Research in education itself has produced valuable information relative to problem solving. An investigation of the writing and research in the above areas should produce findings germane to the designing and conducting of learning experiences appropriate for improvement of problem-solving ability.

Assumptions

The following assumptions are made in this study:

1. Many terms inherent in dealing with problem-solving abilities--critical thinking, reflective thinking, scientific thinking, scientific method, and similar terms--represent approximately the same basic areas of human behavior. In this study these terms are treated as interchangeable.

2. Problem-solving abilities can be improved through experiences offered in formal education.

3. Experiences offered in industrial arts classes can contribute to the improvement of problem-solving abilities.

4. Availability of principles relative to the designing of learning experiences for improvement of problem-solving abilities can facilitate teacher effort.

Delimitation

The following delimitations are made in this study:

1. The source of principles derived from educational philosophy is limited to selected works of John Dewey supplemented by writings of William Kilpatrick. The authoritative voices of Dewey and Kilpatrick complement each other and they have colored the character of American education to an extent unsurpassed by other educational philosophers. It is therefore desirable that a sustained inquiry be made into the principles they have enunciated.

2. The source of principles derived from experimental research is limited to studies which state that they are researching problem solving. This limitation is needed to set problem-solving research apart from the multitude of studies in related topics. Experimental research which is directly concerned with conditions and practices for improving problem-solving ability is the point of this search. Included are both individual and synthesizing studies, the latter drawing together significant researches appearing over a period of time.

3. The broad field of research in creativity is not included in this study. It is recognized as an important consideration; but it is excluded because of necessity for reasonable limitations in scope.

4. The topic of evaluating improvement in problem-

solving abilities is not included in this study.

5. Treatment of the ethical implications of determining appropriate subject matter for problem solving is not included in this study. It is not concerned with setting rules for valuing problem-solving subject matter. Its purpose is to clarify principles for developing the individual's ability to solve problems, not to determine the ethical implications of the problems upon which this ability is brought to bear.

It is recognized that problem solving can be used to reach ends which a society regards as detrimental. Cracking a safe is representative of putting problem-solving ability to use for a negative end. Similarly, problem-solving ability can be employed to accomplish achievements which are beneficial to society. The development of vaccines, such as the Salk poliomyelitis vaccine, illustrates method of science working toward a positive end. Problem-solving ability also can be focused on goals which may be either positive or negative. The development of atomic energy is a case in point. It has been used for both peaceful and destructive purposes.

It is not the intention of this study to examine the values of American society nor to attempt to argue for or against them in order to settle upon which ones provide beneficial ends for problem solving.[2] That the subject

---

[2]An exception is made in the next chapter when it is pointed out that democratic process in democratic society is largely dependent upon problem-solving ability.

matter of problem solving is in need of scholarly attention is not questioned, nor is it denied that educators should address themselves to this question. It simply is not the subject matter to which this study is aimed. Rather, assuming that society has made decisions as to where its good lies, problem solving as a method and objective of the educational process is an instrumentality for advancing society along a decided path. This inquiry attempts to develop principles for improving the instrumental ability.

Definition of the Problem-Solving Situation

Problem solving may be defined broadly as behavior directed toward the maintenance of equilibrium. Life can be regarded as a continuous process of maintaining balance in the face of equilibrium-disturbing situations.

A situation which calls for problem-solving behavior must set a problem. A problem consists of a goal, a goal-blocking obstacle or difficulty, and motivation or drive to strive toward the goal: hence, restoration of equilibrium. Thus, when there is a problem to be solved, there is a problem-solving situation. The thinking, attitudes, and actions an individual exhibits in attempting to define his goal, overcome difficulty, and reach his objective comprise problem-solving behavior.

The Encyclopedia of Educational Research contains the following general definition of problem solving:

> Problem solving is obviously not confined to arithmetical or quantitative situations but may arise whenever the individual is confronted by an obstacle or a task which he understands but to which he has no immediate answer in behavior. (4:649)

For the purpose of this study, it is necessary to define problem solving more specifically. A necessary consideration which helps to define problem solving has reference to the kinds of behavior or ready responses with which the individual responds to problem situations. Problems which are adequately solved through habitual behavior are excluded from the definition. Robert Thorndike gave three elements which are common to all authentic problem-solving situations. The third serves to reinforce exclusion of habitual behavior.

1. The individual is oriented toward a particular objective and motivated to reach it. He has an end in view.
2. Progress toward the objective is blocked.
3. Available, habitual response patterns are not adequate to permit the individual to surmount the obstacle and proceed toward his objective. (6:193)

In his definition of problem solving, William Brownell included the condition that the problem solver "knows of no direct means of satisfaction" at the time, implying the exclusion of habitual behavior. (1:416)

The preceding illustrations point up the necessity of excluding from consideration situations in which habitual, automatic, unthinking responses are performed in the process of equilibrium adjustment. An authentic problem-solving situation demands awareness and conscious consideration of the response to be used. Problem solving requires conscious intellectual activity.

There is, nevertheless, a kind of habitual behavior which is highly desirable and worthy of notation. It is the educational objective about which this study is centered--the individual's habitual use of problem-solving method when he is faced with problem situations. A liberal interpretation of the meaning of habit is required here for it assigns a meaning quite different from the unthinking and automatic connotation usually implied.

Closely related to non-habitual behavior is a necessity for awareness or consciousness throughout a true problem-solving situation. If the individual is not consciously aware of his predicament, no problem-solving situation exists. A vague awareness of frustration is not enough. The individual must have sharp recognition and identification of his desired goal of the level of conscious thought when he is attempting to reach a solution. Thorndike underscored the need for awareness or consciousness when he said,

> one aspect of solving a problem is for the individual to become more sharply and accurately aware of the exact nature of the problem which he faces. But the existence of a problem, as we use the term, implies some awareness of an end to be attained. (6:194)

A pair of grimy hands may result from an evening's work in the basement home workshop. This commonplace situation can be cared for by a moment's scrubbing with soap and water in a habitual manner and is thus not a problem-solving situation. The problem has already been solved and incorporated as a habitual response. However, if the hands fail to come clean due to stubborn stains, a true problem-solving situation may be developing. As soon as the individual realizes his habitual mode of attacking dirty hands has been inadequate his awareness or consciousness arises to create a problem-solving situation. He may try to recall the cause of the stain, and identify it as varnish. Not having any paint and varnish remover, he may search his background of experience trying to think of an effective substitute solvent. Then he may remember he has lacquer thinner that will suffice. Judicious use of it removes the obstacle and he reaches his goal of clean hands.

The foregoing illustration represents a relatively simple problem-solving situation. In reality, problems range tremendously in complexity, in scope, and in subtlety. They may vary from simple and tangible to such complex problems as world disarmament. Brownell placed problems midway along a continuum which stretches from the "puzzle" at one end to the "completely familiar" at the other. (1:416) The "puzzle" is less of an authentic problem situation because it represents a task in which success is primarily the result of accident, rational attacks being of little value. The "completely familiar," likewise, is less of a true problem situation because satisfactory responses are automatic. On the scale, the relative position held by any given problem varies with the individual who experiences it. Proper footnoting form may be a problem for one person and a commonplace procedure for another. Tying shoelaces may be a puzzle for a two year old, a problem for a five year old, and habitual behavior for a seven year old.

The presence of motivation toward satisfaction of a need, or attainment of a goal is a qualifying condition in the definition of the true problem-solving situation. If the individual lacks motivation to proceed, problem-solving behavior will not materialize in spite of the presence of other necessary conditions including goals, obstacles, and consciousness.

Closely associated with motivation or drive is the idea that genuine problems are highly subjective. That is, there is inherent in authentic problems a high degree of personal involvement or attachment. Teacher assigned problems can be low in subjectivity. Problems generated intrinsically are likely to possess a high degree of subjectivity and motivation. Put bluntly, the individual should be possessed by the problem.

To recapitulate, individuals engage in problem-solving behavior when attempts to achieve goals are blocked, and when no immediate answer is available. Five basic elements of an authentic problem-solving situation are:

1. There should be an objective or goal in view.
2. There should be something blocking the objective.
3. There should be awareness or consciousness of the goal and blocking obstacle. There should be intellectual activity.
4. There should be a high degree of subjective identification or motivation.
5. Problem situations at both ends of a problem difficulty continuum, which range from the extremes of the completely familiar (rectifiable through unthinking, habitual response) to puzzles (solvable through accident, rational means being of little consequence), are less desirable problem situations than those in between.

The foregoing definition of a problem situation may seem to include only situations an individual finds himself in as a matter of circumstance, quite apart from any self direction or choice. At the time of a national election one may be faced with a problem situation when he determines how to cast his vote. The election which brings about the problem situation is instituted independently of his willing it to happen. Likewise, when a lawnmower breaks down part way through the mowing of a lawn, the individual who wants his grass cut is faced with a problem instituted by conditions beyond his will. Plainly he is caught in a situation he did not ask for. Problem situations caused by circumstances beyond an individual's control are often fruitful sources of problem-solving activities for educational purposes.

What about problem-solving situations which are deliberately instituted or willed by the individual? Does engaging in a game of tennis or chess constitute a problem situation as defined above? Checking the foregoing five criteria of an authentic problem indicates that it does. Thus, deliberately instituted problems can quality as authentic problem-solving situations.

From the standpoint of the teacher who is interested in improving student's problem-solving abilities, the solution of a problem is not as important as the activity involved in the attempt to solve the problem. In terms of additional experience in solving problems and possible improvement of problem-solving abilities, it is not winning a game of chess or finishing a mosaic wall plaque that is of greatest importance. It is the benefit resulting from the activity of solving the opponent's game or of creating the wall plaque. It is the active process of solving problems which should interest the teacher.

It is the task of the teacher to engage his students in problem situations. He may employ either the circumstantially or the deliberately instituted problem situation.

He should be careful to insure that the problems used suit the criteria for an authentic problem-solving situation.

Problem Solving As Method and As Objective

Problem solving is regarded as a method, a process, a procedure to be followed in reaching goals for which there is no immediate, successful response available. In this sense, the term problem solving is used as a noun, a name given to an entity, a process.

Historically, solutions to problems have been sought principally by appeal to religious and secular authorities, intuition, reason, and to empirical experimentation. Although all these approaches are still in use, the last two loom large in our contemporary culture. Problem solving as a method involves reason and experimentation.

Problem-solving method has been described by various authors. John Dewey was one of the first. He was paraphrased by Edward Hodnett as follows:

1. Perplexity--an awareness of the problem.
2. Analysis and clarification by observation and reflection--definition of the problem.
3. Consideration of different solutions or working hypotheses for solution of the problem.
4. Verification of the solution chosen. (3:3)

There is no single procedure for solving problems because of the large variety of problem situations, differences in the individuals involved, and many other factors. The order of steps actually taken may not follow Dewey's model. Nevertheless they do represent the components of the problem-solving method.

Problem solving is also regarded as an objective of the educational process because youngsters must learn to solve problems in order to live in society. They need to become skillful in the use of problem-solving method. Problem-solving ability (method) is fundamental to the democratic way of life; its development, therefore, should be a primary goal of education. Thus, ability in problem-solving method becomes an objective of education because of its significance as a method.

Industrial Arts Defined

Gordon Wilber defined industrial arts as the "phases of general education which deal with industry--its organization, materials, occupations, processes, and products--and with the problems resulting from the industrial and technological nature of society." (7:2) This fairly typical definition stresses industrial arts as being part of general education. Industrial arts instructional programs are found at the elementary, secondary, and college levels.

Research Method

Research has been defined in the Dictionary of Education as "careful, critical, disciplined inquiry, varying in technique and method according to the nature and conditions of the problem identified, directed toward the clarification or resolution (or both) of a problem." (2:464)

Among the various types of educational research, this study is best classified as philosophical. It is not an experimental research study, although it uses data from such studies; nor is it historical, although a historical approach is used in reviewing the concern of industrial arts teachers regarding problem solving.[3]

Philosophical research has particular value in situations in which the need is to relate a wide range of evidence to a specific problem. Philosophical research can bring a broad range of evidence into focus on one problem. Experimental research can verify hypotheses and find facts; but it cannot interpret their significance to the world, nor set its own direction. The significant role of philosophical research is to relate a wide range of evidence to problems, thus setting the task for experimental research through rational means.

Carter V. Good's definition of synthetic research seems to describe adequately the role and purpose of philosophical research as it is used in this study.

> Research of the deliberative type that has for its purpose the synthesis of findings originating in a number of different studies and perhaps emanating

---

[3]Appendix A.

> from diverse schools of thought, involving comparison, evaluation, and interpretation, usually with respect to a larger frame of reference that will permit reconciliation of conflicts or inconsistencies and impart new meanings to the whole. (2:465)

The method of philosophical research has been analyzed by H. L. and J. R. Smith, and identified as Dewey's five phases of reflective thinking. They are,

> (1) a felt difficulty, (2) its location and definition, (3) the suggestion of a possible solution, (4) the development by reasoning of the implications of the solution, and (5) further observation and experimentation leading to its acceptance or rejection. (5:117)

These need qualification, however, because the fifth of Dewey's phases of reflective thinking cannot be carried out without experimentation. Philosophical research is based on reflective thinking employing only past experience and accumulated knowledge without experimental verification of hypotheses, so it may be concluded that philosophical research method can be identified with Dewey's five phases of reflective thinking minus the word "experimentation" in the fifth phase. This does not imply that philosophical method is unconcerned with projection into the future of the consequences of its hypotheses, for it is concerned. Philosophical research projects through rational means, employing accumulated evidence of past experience, rather than through experimental means.

Preview of Succeeding Chapters

Theoretical aspects of problem solving as an objective of instruction are examined in Chapter II. The chapter investigates a system for deriving educational goals. The roots of problem solving as an objective are examined, and a broad statement of the objective is translated into a series of definitive phrases descriptive of desired behavioral outcomes. A rationale is then developed for the contribution of industrial arts instruction to this goal.

In Chapter III, problem solving is treated as a method of teaching and learning. The method is described, and its strengths are cited. Emphasis is given to the inseparability of objective and method, or an ends-means continuum. The conditions of educative experience are developed as prelude to a search for more specific principles helpful in designing and guiding learning experiences which will improve problem-solving abilities.

In Chapter IV, the writings of Dewey and Kilpatrick are searched for concepts pertinent to the purpose of this study. Reports and summaries of experimental research are examined for evidence of principles germane to the improvement of problem-solving abilities in Chapter V.

Principles from the two sources are merged in Chapter VI, following a definition of principles and an explanation of their use. The principles developed in the study are then applied to the teaching of industrial arts in Chapter VII. Representative teaching-learing situations are described in some detail; and emphasis is given to showing the principles in use in these situations. The study is then summarized in Chapter VIII.

Bibliography

1. Brownell, William A. "Problem Solving," The Psychology of Learning. Forty-first Yearbook of the National Society for the Study of Education, Part II. Chicago: University of Chicago Press, 1942.

2. Good, Carter V. (ed.) Dictionary of Education. 2d. ed. New York: McGraw-Hill Book Co., 1959.

3. Hodnett, Edward. The Art of Problem Solving: How to Improve Your Methods. New York: Harper & Brothers, 1955.

4. Russell, David H. "Higher Mental Processes," Encyclopedia of Educational Research, a Project of the American Educational Research Association. 3d. ed. Edited by Chester W. Harris with the assistance of Marie R. Liba. New York: Macmillan Co., 1960.

5. Smith, H. L., and Smith, J. R. An Introduction to Research in Education. Bloomington, Ind.: Educational Publications, 1959.

6. Thorndike, Robert L. "How Children Learn the Principles and Technique of Problem Solving," Learning and Instruction, Forty-ninth Yearbook of the National Society for the Study of Education, Part I. Chicago: University of Chicago Press, 1950.

7. Wilber, Gordon O. Industrial Arts in General Education. Scranton, Penna.: International Textbook Co., 1948.

CHAPTER II

PROBLEM SOLVING AS A GOAL OF EDUCATION

Within the framework of this study, it is deemed necessary to establish in this chapter the improvement of problem-solving abilities as an objective of education before moving on in subsequent chapters to consideration of problem solving as method, and then to development of more specific principles for improving problem-solving abilities. First, an explanation of a pattern for the derivation of educational goals is presented to provide a point of reference from which problem-solving ability will be developed as an imperative need of society and an essential aim of education. Problem-solving abilities then will be defined in terms of expected behavioral outcomes. Finally, a rationale will be developed for the contribution of industrial arts instruction to the improvement of problem-solving abilities.

Basis for Derivation of Educational Goals

A study of the writings of a score of curriculum authorities produced information which, when sorted and synthesized, resulted in a list of five considerations vital to the derivation of educational goals:

1. Individual Needs--Basic human needs arising from the developing individual.
2. Societal Needs--Basic needs created by the demands of social living.
3. Values--Determinants of the good life.
4. Theory of Learning--Knowledge of how people learn and what they can learn.
5. Subject Matter--Content needed for satisfaction of needs.

Close examination of the above list shows differences in function among the various considerations. The first three are primary sources of educational goals. The fourth can be viewed as an agent performing a screening action necessary to select a reasonable number of consistent and feasible aims from the many presented for attention by the primary sources. (4:22-28) The fifth consideration, subject matter, can be viewed as content essential to realization of the three primary sources of educational goals. Subject-matter mastery can be an objective or goal indirectly as it is given significance by its relationship to the three primary sources. In this sense, subject-matter objectives are instrumentalities toward end goals rather than ends in themselves.

For example, if one assumes that an examination of the three primary sources of educational goals indicates a necessity to comprehend and appreciate the complexities of converting raw materials into socially useful products, then he can establish a foundation for identifying subject matter as content necessary for satisfaction of human need. Content can include such components as materials, tooling processes, occupations, power, product design, consumer needs, and transportation. Hence, an understanding of subject matter as an interrelationship of the components of content can result in the concept that subject-matter objectives are instrumentalities toward satisfying primary educational goals.

Except for purposes of analysis, it is unrealistic to separate the first two primary sources of educational goals. Individual and societal needs are thoroughly entwined. Therefore, no attempt will be made in this study to distinguish sharply between them. (12:5-6) Educational goals originate in the values and persistent needs of individuals in relationship to their society. Satisfaction of some of the needs becomes the basic purpose of formal education. True, the informal educational experiences of living contribute to satisfaction of needs; but society, to insure a measure of organized attention to them, has instituted formal education.

Ability in Problem Solving Needed to Help Cope With Change

Change is a constant reality. Man's adapting to the changing conditions of his environment is a continuing process, and only those who can adequately meet its demands survive. Until the twentieth century, the pace of change was comparatively slow. To a degree, men were able to keep the pace by relying on the well of human experience, their concepts of divine authority, their intuition and superstitions.

Today, however, throughout most of the world, the pace of change has been accelerated rapidly, raising serious questions as to man's ability to make adequate adjustment. Fifty-eight per cent of the population employed by United States industry is working at jobs that did not exist fifty years ago. (8:8) In Africa, the population is culturally far less ably equipped than that of this country to adapt to change brought on and speeded up by science and technology. Yet, in one generation, many of its people are attempting to make the transition from life as uncivilized tribesmen to the life of fairly enlightened men involved in modern occupations. Fresh from the Ethiopian bush where their parents are uncivilized, boys have been trained as commercial airplane pilots.

John Fuzak, commenting on the developing speed of change, said:

> It seems that where man once had centuries to adjust to his ways of living, he now has years, or even months. In this situation, what will happen to occupations, to government, or to any social institution is impossible to predict. (11:27)

If the changes of the future could be confidently forecasted, educational planners could adjust their direction accordingly. Since the problems of prediction are so complex and loaded with possibility of serious error, confidence can be placed only in the most general predictions--and these are of little value. It is, nevertheless, unavoidable that "we have to prepare our youth to live amid conditions yet to come, amid conditions now unknown to us." (14:65) Kilpatrick observed that "it is the duty of the school to help rear the young to be ready as far as possible in both attitude and ability to face the problems of their civilization." (15:219)

It is offered here that our young should be equipped with problem-solving ability as the tool most valuable for meeting change in an unpredictable future. Hullfish and Smith supported this position, agreeing, "with John Dewey that to 'claim that intelligence is a better method than its alternatives, authority, imitation, caprice and ignorance, prejudice and passion, is hardly an excessive claim.'" (13:262)

The increasing complexity of life coupled with rapid change negates the fixed-response approach to education. It is not enough to expose our youth to the best knowledge and concepts available at present--although these are necessary ingredients to education--because so much is subject to change. In speaking of science education, Ralph W. Tyler said:

> . . . the individual today is not able to understand his natural world and to take intelligent responsibility for his actions in controlling and using natural phenomena if he merely remembers the explanations presented in a textbook when he was in school. He must understand science as a continuing process of inquiry, not as a firm set of answers to particular questions. (20:31)

It would seem to be no stretch of truth to suggest that the same kind of thinking can apply to our social institutions and other aspects of daily living.

The need for problem-solving abilities thus becomes increasingly significant in determining meaningful relationships and in giving direction to living. Fuzak emphasized that "the safest insurance for adequate adjustments and wise decisions [in face of change] is the improved problem solving ability of each individual." (11:27) It becomes an unavoidable responsibility of the schools to provide for this need.

Problem-Solving Ability, The Keystone of Democracy

An examination of the philosophy underlying American democratic society establishes "belief in the integrity and worth of each individual, equality of opportunity, faith in the free play of intelligence, and social sensitivity." (2) Democracy is dependent upon the free play of intelligence, but not without responsibility for consideration of the other factors in the above statement. Before an individual or members of a group commit themselves to action they must exercise intelligence to determine and weigh the consequences of the action in light of democratic values. A state legislature should consider the consequences of reducing financial appropriations for public education in a thorough and thoughtful manner before acting. In a democracy, responsible problem solving thus is an important factor in determining the course of action fairest to all involved.

Democracy can be defined as a form or method for reaching decisions cooperatively. It can be contrasted with other methods of decision making in which a superior authority independently arrives at decisions on matters which seriously effect subordinates. Fuzak described democracy as:

> a form of socio-governmental organization in which there is freedom of opportunity to participate in making decisions on matters of individual or group concern, and equality of obligation or responsibility to abide by such decisions and carry them out. (9:12)

If democracy provides a method for individuals and groups to use in solving the problems of life, then individuals should have understandings, abilities, and attitudes favorable to the method. Problem solving is needed equally by individuals and by society if the democratic way is to function successfully.

Reflective thinking is fundamental to democratic efforts of guiding social change and reconstruction. For a society to survive, it must have a built-in ability to adjust to changing conditions brought about by internal and external forces. Our country is dedicated to democratic method in preference to others as a means of guiding social change. This emphasizes the need for reflective thinking.

The role of the school relative to social change should be to focus democratic problem solving on central issues. By so doing, the school can help the built-in compensation or adjustment mechanism of democracy, democratic method, to function more competently when facing and adjusting to needed change. According to Hullfish and Smith the responsibility of schools "is to contribute to society, through their graduates, an increasingly informed, sensitive, and critical intelligence." (13:264) In that our schools are institutions of the democratic society which established them, it is reasonable that they reinforce or perpetuate the essential ingredients of democracy--one of these being reflective thinking as employed in the solving of problems. Fuzak affirmed this idea when he said,

> democratic education must promote on the part of every individual, and in the highest possible degree, the ability to wrestle with problems independently--to think reflectively. <u>It must teach people how to think rather than what to think</u>. (9:12)

Increasing student abilities in democratic method or problem solving should certainly be a prime objective of education. It is the role of the school in a democracy to place faith in the free play of intelligence and to promote its practice as the primary means of solving individual and social problems. This idea implies need of opportunity for students to engage in activities, as a portion of their ongoing educational experience, which promote the practice of the free play of intelligence.

Examination of current educational practice reveals a wide range of degree of acceptance of such activities. Note, for example, the industrial arts teacher who sincerely involves his students in making decisions relative to a plan for cleaning up the laboratory at the end of the class period, as contrasted with another industrial arts teacher who announces and imposes without class discussion, his own experience-proven, "sure-fire" clean-up system. The latter appears to be as devoid of faith in the free play of intelligence as he is in providing opportunity for its practice. The former displays both faith in and practice of intelligent reflection, the democratic method. Examination of procedures used by student councils, the rationale for which, basically, is experience in democratic method, furnishes a wide range of examples in degree of consistency with the rationale.

If the objective of democratic problem solving is to be promoted significantly by our schools, teachers must believe in it and furnish challenging, guided experiences as built-in daily occurrences. "As he [the student] engages in problem solving and judgment, the student must closely approximate the democratic process." (22:32)

Dewey's Reasons for Reflective Thinking as an Aim of Education

Dewey described and illustrated three values which accrue from the exercise of thought and which are germane to a rationale for including development of problem-solving abilities in the aims of education.

First, reflective thinking makes possible action which has conscious aim. "Thinking," Dewey said,

> enables us to direct our activities with foresight and to plan according to ends-in-view, or purposes of which we are aware. It enables us to act in deliberate and intentional fashion to attain future objects or to come into command of what is now distant and lacking. . . . It converts action that is merely appetitive, blind, and impulsive into intelligent action. (6:17)

Second, thought "makes possible systematic preparations and inventions." (6:18) In order to facilitate intelligent action, man sets up signals to himself so he may anticipate meanings and consequences, and means of securing or avoiding them. A variety of traffic signs, such as "sharp curve" and "slow," are placed along highways to warn drivers so that they may safely and directly anticipate the road ahead, thus facilitating the securing of the desired ends. The scientist records and publishes the results of his investigations using the invention of the written word so others may see and profit from the witness marks along the trail he has blazed.

Third, thinking enriches the meaning of things. To some, a log of wood represents a form of fuel or source of building material; to others, it has added significance as a combination of certain chemical elements or as testimony of climatic conditions which existed during its growing period. Reflective thought suggests added significance, thereby enriching the meaning of things.

Dewey followed his explanation of the values inherent in reflective thinking with a principal reason why reflective thinking should be a required goal of education. He believed that the potential of the values could not be realized if left to chance experience of life. "For anything approaching their [problem-solving abilities] adequate realization thought needs careful and attentive educational direction." (6:22)

Learning Depends on Reflective Thinking

Dewey viewed learning as being dependent in large measure upon effective experiencing. (5:179-192) The meaning of effective experiencing is sharpened by substitution of the word educative for effective. The quality of learning experiences range from highly educative to completely mis-educative. One of the principal factors in making experience educative is reflective thinking. An experience that lacks the element of reflective thinking is mis-educative.

Hence, it can be stated that learning is highly dependent upon the degree of reflective thinking involved. In a very real sense, ability in reflective thinking should be an educational goal in order that the quality of learning may be enhanced.

Validating the Problem-Solving Objective

In their study of the fundamentals of curriculum development, Smith, Stanley and Shores suggest that educational objectives should be examined for soundness by subjecting them to a five-point validating criteria. Objectives to be considered sound must

1. be conceived in terms of the demands of the social circumstances;
2. lead toward the fulfillment of basic human needs;
3. be consistent with democratic ideals;
4. be either consistent or non-contradictory in their relationships with one another;
5. be capable of reduction to behavioristic terms. (19:253)

The use of the term "behavioristic" in the phrase immediately above may be clarified as meaning behaviors stated in terms descriptive of and definitive of the desired behavioral outcomes of the education process, including a total range of behavior from overt physical actions to covert cognitive and affective areas. More simply, "capable of reduction to behavioristic terms" means that general statements of educational goals should be converted into definitive statements, descriptive of the behavior which is desired as a resultant of educational experience. This meaning should not be confused with behavioristic psychology.

The problem-solving objective meets the first three standards. No other instructional objectives are under consideration in this study, so point four is not germane. It is probable, however, that this standard would be met if problem solving were compared with other objectives. Regarding the last standard, problem solving is capable of reduction to behavioristic terms, as will be shown in the next section.

In summary, problem-solving abilities are crucial in learning, in adjusting to changing environment, in keeping democratic method vital, in making possible and facilitating purposive action, and in enriching meanings. Improvement of problem-solving abilities is a prime need of individuals and of society, and is, therefore, a legitimate objective of formal education.

Improvement of Problem-Solving Abilities Will be Facilitated Through Conscious Planning by Teachers

It has been held by some that improvement of problem-solving abilities will result indirectly, as a concommitant outcome of the pursuance of other goals. That some improvement may occur cannot be denied. Greater gains are possible, however, when the teacher consciously plans learning experiences with the goal of problem-solving ability in mind. To suppose otherwise would be to negate the basis for planning in education and elsewhere. When being taught for improvement in reading ability the student may make some gains in ability to spell certain words. But the teacher can be more certain of student gains in spelling ability if he consciously plans ways for achieving this goal. Direct planning is also a matter of economy of effort.

Dewey said that "beyond a somewhat narrow limit, enforced by the necessities life, . . . [problem solving abilities] do not . . . automatically realize themselves. For anything approaching their adequate realization, thought needs careful and attentive educational direction." (6:22) It is therefore regarded as a sustainable principle that improvement of problem-solving abilities for optimum realization requires conscious planning by teachers.

Problem Solving Defined Behaviorally

It has been shown that improving problem-solving ability is a worthy educational goal, derived from individual and societal needs. The next task is to plan an educational program which contributes to the achievement of this goal. In overview, this planning includes (1) definition of objectives in statements of expected student behavioral outcomes, (2) selecting or designing appropriate learning experiences, (3) evaluation of growth in terms of behavioral outcomes, and (4) conversion of the preceding analysis into a workable plan of action for day-to-day teaching. This study is concerned primarily with phases one and two; this chapter deals with phase one.

Tyler advocated presenting educational goals in definitive statements of expected behavioral outcomes; (4: 28-40) and another source suggested that secondary school outcomes could be improved through such a procedure. (7:34) Pointing out the necessity of defining objectives in terms of expected behavioral outcomes before proceeding to the design of appropriate learning experiences, Gordon O. Wilber said:

> Since behavior changes are the desired outcome, the objectives should be analyzed in terms of such changes as appear desirable. In other words, the teacher may well look at each objective and ask himself, "Just what behavior changes do I expect from my students as evidence that this objective has been attained?" This is a step which cannot be ignored if concrete and tangible results are desired from each of the accepted objectives. Too frequently aims and purposes remain vague and unattainable because their true significance is not disclosed by a searching study of what is required by way of behavior changes. (23:46)

A search was conducted for sources of comprehensive behavioral descriptions of problem-solving abilities which might represent behavioral goals for which appropriate learning experiences could be devised. Few were found even though current curriculum theory advocates such behavioral descriptions of educational objectives. Paul Dressel and Louis Mayhew, in 1954, provided a list of problem-solving behaviors or abilities which appears to be fairly comprehensive, particularly in the cognitive area. It serves to represent an amplification of the general goal, of improvement of problem-solving abilities, by listing a series of specific abilities descriptive of desired problem-solving behaviors.

A TENTATIVE LIST OF THE PROBLEM-SOLVING ASPECTS
OF CRITICAL THINKING

1. Ability to Recognize the Existence of a Problem
   a) To recognize related conditions in a situation.
   b) To recognize conflicts and issues in a situation.
   c) To locate "missing links" in a series of ideas or incidents.
   d) To recognize problems which have no solution.
2. Ability to Define the Problem
   a) To identify the nature of the problem.
   b) To understand what is involved and required in the problem.
   c) To recognize ways in which the problem can be phrased.
   d) To define difficult and abstract elements of the problem in simple, concrete and familiar terms.
   e) To break complex elements of the problem into workable parts.
   f) To identify the central elements of the problem.
   g) To place the elements of the problem into an order in which they can be handled.
   h) To eliminate extraneous elements from the problem.
   i) To place the problem in its context.
3. Ability to Select Information Pertinent to the Solution of the Problem
   a) To distinguish reliable and unreliable sources of information.
   b) To recognize bias upon which information is selected and rejected.
   c) To recognize information relevant to the solution of the problem.
   d) To select adequate and reliable samples of information.
   e) To systematize information.
   f) To select information from personal experience relevant to the solution of the problem.

4. Ability to Recognize Assumptions Bearing on the Problem
   a) To identify unstated assumptions.
   b) To identify unsupported assumptions.
   c) To identify irrelevant assumptions.
5. Ability To Make Relevant Hypotheses
   a) To discover clues to the solution of the problem.
   b) To formulate various hypotheses on the basis of information and assumptions.
   c) To select the more promising hypotheses for first consideration.
   d) To check the consistency of the hypothesis with the information and assumptions.
   e) To make hypotheses concerning unknown and needed information.
6. Ability To Draw Conclusions Validly from Assumptions, Hypotheses, and Pertinent Information
   a) To detect logical relationships among terms and propositions.
   b) To recognize necessary and sufficient conditions.
   c) To identify cause and effect relationships.
   d) To identify and state the conclusion.
7. Ability To Judge the Validity of the Processes Leading to the Conclusion
   a) To distinguish validly drawn conclusions from others chosen for example, because they are in accord with values, preferences, and biases.
   b) To distinguish a necessary inference from a probable one.
   c) To detect formal logical inconsistencies in the argument.
8. Ability To Evaluate a Conclusion in Terms of Its Application
   a) To recognize conditions which would be necessary to verify a conclusion.
   b) To recognize conditions which would make a conclusion inapplicable.
   c) To judge the adequacy of a conclusion as a solution of the problem. (1:177-178)

The Russell Sage Foundation report on a study of behavioral goals of general education for secondary schools, published in 1957, included a similar list descriptive of problem-solving abilities.[1] Ellsworth Osbourn dealt with

---

[1]See Appendix B.

the same subject in a magazine article in 1956. (18:388-392)

Handbook I of The Taxonomy of Educational Objectives classified all educational objectives as cognitive, affective, and psychomotor. (3:7-8) It suggested that any stated educational objective can be classified in the taxonomy. Accordingly, the preceding list of problem-solving behaviors would be considered largely cognitive in character. It is not without affective overtones, however, because cognitive activity is colored and controlled to a large degree by attitudes.

The importance of attitudes in problem solving was stressed by Dewey.

> Because of the importance of attitudes, ability to train thought is not achieved merely by knowledge of the best forms of thought. Possession of this information is no guarantee for ability to think well. Moreover, there are not set exercises in correct thinking whose repeated performance will cause one to be a good thinker. The information and the exercises are both of value. But no individual realizes their value except as he is personally animated by certain dominant attitudes of his own character. (6:29)

He advocated a union of attitudes, knowledge about principles of reasoning, and technical skill as essential components in reflective thinking. If compelled to make a choice among the three components, however, as to which is the most essential to improvement of problem-solving ability, he said he would choose attitudes. (6:34) Dewey defined these attitudes as open-mindedness, wholeheartedness, and responsibility. (6:30-33)

An extended list of attitudes leading toward improvement of problem-solving ability would be similar to a list of attitudes suggested as desirable by Dressel and Mayhew for rational and scientific thought.[2] Many other writers have identified attitudes which are descriptive of the affective portion of the problem-solving objective. (16:30-31)

An examination of problem-solving situations reveals the presence of psychomotor behaviors: physically oriented abilities like manipulative skills involved in handwriting, or stick-handling a hockey puck past an opponent. The presence of psychomotor behavior in a problem-solving situation can be illustrated in an example provided by students engaged in making arrangements for their class dance. They may recognize the advisability of publicizing the affair, and decide to make several dozen publicity posters for display in the school and community. Seeking an available and practical way of producing a number of posters may lead to selection of the silk screen process. The preparation of the poster design, cutting of the stencil, and adhering of the stencil to the screen all require varying degrees of psychomotor skills. This particular illustration also involves cognitive and affective abilities, indicating the need for all three in many problem situations. Many

---

[2] See Appendix C.

problems, however, can be solved exclusive of psychomotor behaviors.

Attempts to define behaviorally the many specific psychomotor abilities included in solving problems could be almost endless. There are so many specific abilities useful in solving a wide variety of problems that it would be a lengthy task to begin to identify all of them.

The question of which psychomotor abilities the school should seek to develop is not easy to answer. It can be answered, however, by establishing valid criteria based on the purposes of education one supports. If the function of education is to provide for the development of the knowledges, attitudes, and psychomotor abilities necessary for coping with the common needs or problems of all persons, then those psychomotor skills identified as common should be included. Certainly the development of the psychomotor abilities involved in reading, writing, speaking, and drawing are representative examples. If education is to provide for the development of specialized knowledge, attitudes, and psychomotor abilities needed in some degree by all persons because of special interests and occupational needs, then a wide range of psychomotor abilities might be included: skill involved in playing a musical instrument, for example, or in executing an intricate wood carving, or in operating a typewriter.

It is assumed that public education, broadly considered, should contribute to both the common and specialized needs of youth. This assumption is based in part on the fact that attempts to draw sharp distinctions between common and specialized psychomotor needs usually encounter difficulty because of variations in the purposes for which individuals will employ them. Ability to express ideas clearly through the media of pictorial illustration is a common need, aiding in visualization and in communication. The common need becomes a specialized one, however, if an individual eventually uses the skill in pictorial illustration as an engineer, draftsman, architect, or industrial designer.

Although public education should contribute to the needs of both common and specialized psychomotor abilities, emphasis should be focused on common abilities necessary to solve the usual problems of living. If this were not so, the efforts and resources of the public schools could become lost in the host of specialized needs.

Representative psychomotor abilities in problem solving that teachers of industrial arts could seek to develop are:

1. Improvement of psychomotor abilities involved in effective written, spoken, and graphic communication.
2. Advancement of general ability in using common hand and power tools.

It should be mentioned that the maturation level of individuals at particular age levels has a direct bearing upon the behavioral statements made to describe expected outcomes. The statements should be altered for the various developmental levels in direct agreement with the findings of the behavioral sciences. For example, the cognitive abilities of problem solving should be more refined at the secondary school level than at the elementary. Fuzak has shown that there is considerable increase in complex finger dexterity of students during their junior high school years, thus indicating a need for adjustment of their behavioral goal expectations during those years. (10)

In reality, the separation of problem-solving abilities into three categories is artificial and useful only for purposes of analysis and study. The categories are interrelated in the solving of problems.

Contribution of Industrial Arts to the Improvement of Problem-Solving Abilities

A list of educational objectives for secondary schools was compiled in 1938 by the Educational Policies Commission, (17:47-125) and defined behaviorially by Will French and his associates in 1957. (7:92-213) Using this list and assuming the operation of a curriculum organization of separate subjects, it should be the duty of teachers to identify those objectives to which their particular subject areas can contribute. The teachers then should develop their programs consciously aiming at achievement of the identified objectives.

If a subject area does make significant contributions to accepted educational objectives, it should be included in the school curriculum. If it does not, its inclusion should be seriously questioned. In this context, significant contributions mean those contributions that cause positive behavioral change by students in the direction of the objectives being considered, and those that cause reconstruction or reorganization of students' cognitive and psychomotor abilities and attitudes in the direction of desirable behavioral outcomes.

For the purposes of this treatment it is sufficient to define "significant contributions" as those causing positive behavioral change in the direction of the objective under consideration; as those causing reconstruction or reorganization of the individual's cognitive and psychomotor abilities and attitudes in the direction outlined by statements of desired behavioral outcomes.

There are a number of ways for teachers to determine the educational goals to which their subjects can contribute significantly. The means vary in complexity and in accuracy, and they are not exclusive of each other. Some of them are reliance on:

1. A combination of teaching experience, intuition and good judgment.
2. Experimental research designed to determine actual behavior changes.
3. The judgment of expert opinion.
4. Application of philosophical principles and theories of learning.

Using the above means to point the way toward specific objectives to which any subject can contribute can reasonably lead teachers of industrial arts to an assumption that their subject may contribute significantly to the improvement of problem-solving abilities. Thus, the assumption is indicated as grounds basic to the design of this study.

Frequently, the question of identification of the unique contributions of a subject is raised. Numerous examples of this question are found in industrial arts literature. Often much misunderstanding develops among teachers attempting to identify the unique contributions of their subjects. The misunderstanding may be due to differences in interpretation of the term unique. The dictionary meaning of unique is: single, sole, without a like or equal, matchless. (21:930) Accordingly, claims of unique contributions to the goals of education by a subject area imply a singleness exclusive of other subjects. If more than one subject contributes significantly to particular objectives, the contribution should not be termed unique. It would be accurate to describe the contribution as common or joint. Fortunately, most contributions are common. The composite efforts of several subjects reinforce, strengthen, and complement each other.

As to the objective of increasing problem-solving abilities, all subject areas have potential. Dewey said that

> any subject, from Greek to cooking, and from drawing to mathematics, is intellectual, if intellectual at all, not in its fixed inner structure, but in its function--in its power to start and direct significant inquiry and reflection. (6:46-47)

Regarding industrial arts, he believed activity programs have great potential for training thought. (6:216-218)

Although the contribution of industrial arts to the imporvement of problem-solving abilities is not unique, it has several features which may not be shared equally by all subjects. Because of the following features, industrial arts can make a significant contribution to the educational objective of improving problem-solving ability.

1. A wide range of problems are available, varying from concrete to abstract and from simple to complex. Emphasis is usually upon tangible problems involving physical materials which most students can readily comprehend.
2. There is abundant opportunity for students to test experimentally reasoned hypotheses in actual

conditions. They can get almost immediate feedback of the quality and consequences of their thinking.

3. Problems can be tailored to accommodate individual differences.
4. Typical problems in industrial arts have the potential of involving the whole person.
5. Industrial arts problems may be closely identified with here-and-now and true-to-life situations.
6. Opportunity is present for group problem solving of actual social problems generated by class activity.
7. Difficulties usually encountered by teachers attempting to observe and criticize constructively the quality of student thinking are partially modified by the presense of a tangible physical product which can reflect flaws and strengths.

The unique feature of the industrial arts contribution to improving problem-solving abilities is its use of the tools, materials, and processes of industry.

Summary

In this chapter, the basis for inclusion of problem solving as an objective of education was explored. The objective was then defined behaviorally, and a rationale for the contribution of industrial arts to the objective was developed. The stage is now set for consideration of problem solving as method.

Bibliography

1. American Council on Education. General Education: Explorations in Evaluation; the Final Report. A Cooperative Study of Evaluation in General Education directed by Paul L. Dressel, assisted by Lewis B. Mayhew. Washington: American Council on Education 1954.

2. Better Education for Michigan Children and Adults. Lansing, Mich.: Michigan Department of Public Instruction, 1954.

3. Bloom, Benjamin (ed.). Taxonomy of Educational Objectives: the Classification of Educational Goals. Handbook I: Cognitive Domain. New York: Longmans, Green, 1956.

4. Chicago University. Basic Principles of Curriculum and Instruction, Syllabus for Education 360. Prepared by Ralph W. Tyler. Chicago: University of Chicago Press, 1950.

5. Dewey, John. Democracy and Education: An Introduction to the Philosophy of Education. New York: Macmillan Co., 1928.

6. ________. How We Think; a Restatement of the Relation of Reflective Thinking to the Educative Process. Boston: D. C. Heath, 1933.

7. French, Will, and Others. Behavioral Goals of General Education in High School. New York: Russell Sage Foundation, 1957.

8. Furbay, John H. "International Understanding," Industrial Arts Teacher, XIX (May-June, 1960).

9. Fuzak, John A. "Analysis of Developments to Determine Implications for Industrial Arts," Industrial Arts Teacher, XVII (November-December, 1957).

10. ________. The Role of Physical Maturation in Determining the Ability of Junior High School Boys to Perform Complex Finger Coordinative Activities in Industrial Arts, and an Index to Level of Ability, Research Report, June 15, 1957. Chicago: American Technical Society, 1958.

11. _______. "Where are We Going--Up or Out?" Texas Industrial Arts Association Bulletin, IV (April, 1960).

12. Guides to Curriculum Building: Junior High School Level. ("Wisconsin Cooperative Educational Planning Program: Curriculum Bulletin No. 12"). Madison, Wis.: Wisconsin Cooperative Educational Planning Program, 1950 (reprinted 1955).

13. Hullfish, Gordon, and Smith, Phillip. Reflective Thinking: The Method of Education. New York: Dodd, Mead, 1961.

14. Kilpatrick, William H. "The Experimentalists Outlook," Philosophies of Education. Forty-first Yearbook of the National Society for the Study of Education, Part I. Bloomington, Ill.: Public School Publishing Co., 1942.

15. _______. Philosophy of Education. New York: Macmillan Co., 1951.

16. Mason, John M. "An Experimental Study in the Teaching of Scientific Thinking in Biological Science at the College Level." Unpublished Ph. D. dissertation, Department of Education, Michigan State College, 1951.

17. National Education Association of the United States, Educational Policies Commission. The Purpose of Education in American Democracy. Washington, D. C.: Educational Policies Commission, and The American Association of School Administrators, 1958.

18. Osbourn, Ellsworth S. "An Analysis and Check List on the Problem Solving Objective," Science Education, XL (December, 1956).

19. Smith, B. O., Stanley, W. O., and Shores, J. H. Fundamentals of Curriculum Development. Yonkers-on-Hudson, N. Y.: World Book Co., 1950.

20. Tyler, Ralph W. "Science Education for Changing Times: The Behavioral Scientist Looks at the Purposes of Science Teaching," Rethinking Science Education. Fifty-ninth Yearbook of the National Society for the Study of Education, Part I. Chicago: University of Chicago Press, 1960.

21. Webster's New Collegiate Dictionary. Springfield, Mass.: G. and C. Merriam Co., 1957.

22. Wellington, Burleigh, and Wellington, Jean. Teaching For Critical Thinking: With Emphasis on Secondary Education. New York: McGraw-Hill Book Co., 1960.

23. Wilber, Gordon O. Industrial Arts in General Education. Scranton, Penna.: International Textbook Co., 1948.

CHAPTER III

PROBLEM SOLVING AS A METHOD OF EDUCATION

The improvement of problem-solving ability as an educational objective has been established, and expected learning outcomes or behaviors have been treated. The next consideration, and that of the remainder of this study, is the development of principles for designing learning experiences to achieve improvement of problem-solving ability. The major theme of this chapter is the identification and description of a method to be used for achieving this objective with some indication of the method's strengths. Also to receive attention are the relationships of objective to method, of problem-solving method to subject matter, of teaching method to teaching technique, and a description of educative experience.

Problem-Solving Method Described

Once an educational goal has been established it is necessary to find some means for its attainment. Development of ways to achieve goals and guidance of students toward those objectives are primary tasks of the educator. These ways or means are known as methods. Method in education can be regarded as the organization of a series of learning and teaching activities pointed toward the achievement of goals. Methods as teaching procedures are vehicles designed to carry the learners to the projected destination.

There is a direct relationship between an objective's degree of achievement and the method employed to obtain it. Some methods are more appropriate than others for achievement of different goals. The appropriateness of specific methods is prescribed by the objective under consideration. Burleigh and Jean Wellington said:

> Method grows out of a basic concept of aim. Knowing what he wants to accomplish generally, the teacher may then consider specific purposes, and finally decide how best to do what he desires. . . . A basic understanding of where one is going in teaching is essential to the establishment of a method which is really workable for any given teacher. (29:23)

From a variety of possible methods appropriate selections should be made. For example, if the objective is the development of certain motor skills, such as typewriting or playing the clarinet, a method characterized by practice and repetition may be most desirable. Fuzak pointed out however that "the teaching of thinking lies mainly in the method of teaching." He indicated that such a method of teaching was the problem-solving method. (15:585)

There are a number of ways to improve problem-solving abilities including (1) objective study of problem-solving method used by others, (2) determined examination of methods used in one's own problem-solving experience, (3) study of principles and techniques of formal logic, (4) drill in solving synthetic exercise problems or partial problems, and (5) direct experience in grappling with and attempting to solve real-life problems. Employment of the way last mentioned in the above list is using the reflective-thinking or problem-solving method. It is the teacher's most appropriate and promising way to achieve student improvement in problem-solving ability. This is not meant to imply that other methods do not or can not make a contribution; it is meant to indicate that direct experience appears to be the most promising method. A youngster interested in improving his ability as a baseball pitcher, for example, needs opportunities to pitch balls to batters. Observation of how others pitch, examination of his own technique, study of formalized techniques of pitching, and separated practice of specific phases of pitching are obviously helpful to him. The actual pitching of baseballs to batters, however, is relatively indispensable in a pitcher's development. The same kind of generalization can be made about improving problem-solving abilities. Actual experience in solving real problems is indispensable. Fuzak and Dressel both gave support to this principle. (14:12; 11:48) In their book, The Minnesota Plan for Industrial Arts Teacher Education, Micheels and Sommers wrote: "Problem-solving attitudes and skills can be developed only by participation in many meaningful problem-solving activities." (21:48)

Students, in order to solve problems undertaken to improve their problem-solving abilities need to employ reflective thinking or problem-solving method. In structure, problem-solving method is the same as Dewey's description of the phases of reflective thinking. (9:107) Others, including the Wellingtons, Philip Goldstein, Hullfish and Smith, have described the method similarly. (29:31; 16:9-10; 19:217-218) David Russell compared a number of lists of problem-solving steps as compiled by various writers all of whom were in more or less general agreement. (25:256) Dewey's phases of reflective thinking or problem solving are:

> (1) suggestions, in which the mind leaps forward to a possible solution; (2) an intellectualization of the difficulty or perplexity that has been felt (directly experienced) into a problem to be solved, a question for which the answer must be sought; (3) the use of one suggestion after another as a leading idea, or hypothesis, to initiate and guide observation and other operations in collection of factual material; (4) the mental elaboration of the idea or supposition as an idea or supposition (reasoning, in the sense in which reasoning is a part, not the whole, of inference); and (5) testing the hypothesis by overt or imaginative action. (9:107)

Russell put Dewey's phases of problem solving more simply:

> (1) A felt difficulty; (2) its location and definition; (3) suggestion of possible solution; (4) development by reasoning of the bearings of the suggestion; (5) further observation and experiment leading to its acceptance or rejection. (25:256)

The Dewey and Russell statements serve to define and represent models of the problem-solving method to be used and experienced in solving problems.

Method was considered by Dewey to be both general and individual. He said of general method: "There exists a cumulative body of fairly stable methods for reaching results, a body authorized by past experience and by intellectual analysis." (9:200) General methods, then, are those methods which the experience of others has shown to be reliable in effecting ends (solving problems), and which have gained recognition in society.

There are a number of variations of general methods for solving problems. Dressel and his associates said that "most writers on the subject feel that there are many ways to solve problems scientifically and that no one way is necessarily typical of scientific thinking." (11:46) In the field of educational research there are numerous well defined variations in method of attacking problems. Two of them are experimental research and philosophical research. Both represent general methods for solving problems and, although distinct in their approaches, each basically is related to Dewey's problem-solving method.

Individual method was described by Dewey as the specific variations in general problem-solving method that individuals develop through their own initiative and originality. (9:203) A physician, for example, when diagnosing physical disorders uses procedures established in his profession (general method) to guide his deliberations. Still from the general procedures of diagnosis he must develop his own adaptations; and these are known as individual methods.

Among the many variations in problem-solving method, one group of variations can be identified as standard procedures developed and validated by collective experience; the other group can be recognized as individualization of methods. Neither group follows Dewey's model of method precisely. Thorndike emphasized individual variation when he said:

> each problem-solver and each problem to be solved has its own individual characteristics. Diversity rather than uniformity is the rule in the attack upon problem situations. We do not find the problem-solver going neatly and logically through the sequence of steps. . . . Rather, he jumps around, often starting in the middle, returning then to the initial steps, moving back and forth between hypothesis, problem clarification, appraisal of implications, and hypothesis again. Some of the phases may fail to appear. . . . (26: 196-197)

Dewey's description of problem-solving method nevertheless does represent an accurate, serviceable theoretical description of what is included in the process. His model, recognizing general and individual variations, serves as a focal point for reference, further study, and analysis for teachers when planning and conducting learning experiences to improve students' problem-solving ability. Hullfish and Smith, indicating the importance of such an analysis, said:

> The importance of such analysis for teachers is simply that it may help them to gain a feel for the process in which they, with others, are engaged. They may see more clearly their responsibility for getting problems recognized and clearly stated; for eliciting promising hypotheses; for confronting students with facts (or leading them to discover such facts) which, if not explained, place the suggestions in jeopardy, and for helping students move forward in the prediction-and-verification activities which must be completed before any suggestion may be accepted as a valid solution. (19:219)

Relationship of Objectives to Methods

Problem solving as an objective and as method both have been defined, and it is now important to examine their relationship to each other. Experts in curriculum development stress the need for definition of objectives in terms of desired behavioral outcomes, followed by the development of appropriate methods for their achievement. Frequently, little more is said regarding the relationship of ends to means than that the objective in mind determines the appropriateness of the methods to be used. This section attempts to define clearly the bonds of relationship connecting educational means to their ends.

By way of introduction, a brief paragraph restating the function of objectives and means is presented. An educational aim "as a foreseen end gives direction to the activity; it . . . influences the steps taken to teach the end." (7:119) It furnishes a point of reference for discovering possible means available for reaching ends; it suggests order and sequence in means; and it provides a basis for making choices between alternative means. (7:119) In the previous section, methods or means were cast as ways for accomplishing ends.

Objectives and means should not be considered as separate entities except for purposes of analysis. Dewey avoided sharp dualism by regarding them as a continuum distinguished only by nearness or remoteness in time. "We call it end when it marks off the future direction of the activity in which we are engaged," he wrote; "means when it marks off the present direction." (7:124)

A concept of major importance is that ends give significance to means. Means have little significance apart from ends. Consider the need for transportation to and from one's place of employment--an automobile and gasoline. The automobile has value or significance as a means for achieving the end, transportation. The gasoline has significance as means for the end, making the automobile function. Thus, a chain of ends-means relationships is established: the gasoline having significance in terms of the automobile, and the automobile in terms of transportation. If, for some reason, the need for transportation or the value placed upon it should cease, then the automobile and the gasoline as means no longer would be significant or valuable, and the chain would collapse. Dewey gave an excellent illustration of the inseparability of ends and means when he retold a story he credited to Charles Lamb.

> Roast pork was first enjoyed when a house in which pigs were confined was accidentally burned down. While searching the ruins, the owners touched the pigs that had been roasted in the fire and scorched their fingers. Impulsively bringing their fingers to their mouths to cool them, they experienced a new taste. Enjoying the taste, they henceforth set themselves to building houses, inclosing pigs in them, and burning the houses down. (10:40)

If the ends and the means are separated, and the end--eating and enjoying roast pork--has significance apart from the means, there is nothing ridiculous in the story. When the end is estimated in terms of the means and compared with other possible means, then the situation is ridiculous. Thus, it can be seen that ends cannot be separated from the means used to attain them.

Any ends-means dualism is further allayed by the realization that ends can become means in a very real sense. Today's ends become tomorrow's means. Dewey said: "Every end becomes a means of carrying activity further as soon as it is achieved." (7:124) For example, when a student who is also a neophyte educator begins work toward a doctoral degree, he must intimately identify himself with the degree as an essential goal. The doctoral program includes several station points which are sub-goals, such as completion of course work and passing language examinations. The sub-goals represent means for achieving the goal of the doctoral degree. Attainment of the degree also is means for achieving a further end--professional competence and status. It is evident that ends become means, and that means are temporary ends until they have been attained. Ends should not be considered as <u>ends</u> in a final sense; the same is true with means. The progression of ends and means can move on indefinitely, giving cause for the term, ends-means continuum. It should be clear that ends also gain significance as means as they in turn become means of further consequences.

The inextricable relationship of ends and means, or objectives and methods, establishes for the purposes of this study a general principle for educational planning: that of the ends-means continuum. The purposing of methods and objectives cannot be carried on exclusive of each other. Specifically, when teachers apply the principles developed in this study, they should keep the ends-means relationship in mind.

Relationship of Subject Matter and Problem-Solving Method

Subject matter is commonly regarded as being composed of facts, definitions, principles, information, and the like. As such, subject matter is an isolated assemblage of data in need of bridging relationships which will tie it to usefulness in human experience. Subject matter may be useful to the individual if he sets out directly to acquire an encyclopedic collection of it, and useful to the extent that he may later happen to find situations to which it may apply. A relationship of subject matter to the lives of people and to learning becomes dynamic when it is used in solving problems--in establishing a productive working relationship with problem-solving method. Thomas Risk viewed subject matter as something to be used for achieving desired ends. He said that "facts, information, generalizations or any other material used in the activities to acquire the desired ends constitute the subject matter for that situation.

Thus subject matter is what is used rather than what is learned or memorized." (23:267)

Method and subject matter are difficult to separate. "Method," said Dewey, "means the arrangement of subject matter which makes it most effective in use. Never is method something outside of the material." (7:194) And again "thinking no more exists apart from this arranging of subject matter than digestion occurs apart from the assimilating of foods." (9:247) Problem-solving method without subject matter is an impossibility.

Problem-solving method is used to discover and reorganize relationships of subject matter, thus creating an interacting or reciprocating relationship. For purposes of this study, it may be said that subject matter gains its significance and has its orientation within the framework of problem-solving method--of the difficulty being overcome. Selection of subject matter is determined by the problems at hand. This concept does not relegate subject matter to an insignificant position, but rather places it in an honorable one. Hullfish and Smith said:

> To place an emphasis upon the development of thought in the classroom need lead neither to the neglect of knowledge nor to the failure to gain control of important activities. Knowledge, rather, is honored when given work to do in helping individuals reach those appreciative stages of growth where the meaningfulness of their acts is enhanced by their awareness of the controls they are developing. (19:215-216)

Distinction Between Method and Technique

The terms "method" and "technique" are used frequently in educational writing dealing with problem solving. Method has been described in this study as (1) a procedure for attacking problems, and (2) a composite of teaching and learning activities directed toward the achievement of goals. Problem-solving method has been established as the basis for attacking problems and as the basic method for achieving the teaching objective, improved problem-solving ability. Method is the broad procedure; technique is the manner of performing the various steps in the procedure. (23:14) In this study, method is the problem-solving method; and techniques are specific steps employed in solving problems, or in teaching others to solve problems. For example, a technique in problem solving could be the use of a balance sheet to list factors for and against alternative solutions to a problem. The asking of questions calculated to point-up specific elements in a problem situation also illustrates a teaching technique.

Strengths of Problem-Solving Method

A number of studies have compared the relative effectiveness of variations of problem-solving method to other methods more traditional in nature. The studies indicated that variations of problem-solving method achieved equal or superior results. Dressel and his associates observed:

> The effect of emphasis on critical thinking or the scientific method in particular courses has been studied, and the results in many cases have been positive in that improvement in classes planned around the objective has been demonstrated to be greater than in classes taught with more traditional emphases. Usually the increase in the knowledge is equal or greater than that found in classes taught with content emphasis. (11:45)

To those who would interpret and generalize from the apparent results of studies which compare teaching methods, Dressel sounded a note of caution, saying "one must speak only of the 'possibility' of such gains." (12: 21) Several reasons why generalizations are tricky, he added, are differences in design, in terminology, and in instructor enthusiasm and competence. The following studies and statements are offered to indicate particular areas of strength.

A series of studies by Ray, Rowlett, and Moss compared two methods used in teaching concepts typical of different industrial arts content areas.[1] They said they found a problem-solving method to be generally equal or superior to traditional direct telling in initial learning, retention, and transfer.

A study by Knight and Mickelson compared a problem-centered method with a subject-centered method to discover differences in gain relative to rules of action, factual

---

[1]Appendix A, pp. 269-270.

information, and connection of specific rules of action with specific facts. (20:3-7) The results of their study, they said, showed that the problem-centered method was significantly superior in all three areas.

Cook and Koeninger reported that their experiments showed that students taught by problem method, as contrasted with traditional methods, gained an equal amount of information, made twice the gain in change of attitudes, and nearly four times the gain in critical thinking ability. (5:41)

In his book, Psychology and Life, Floyd L. Ruch wrote that "children who are permitted to learn by studying problems of everyday life usually learn more of the solid subject matter than those who are forced to study that same subject matter when it is presented with less attention to the student's interests." (24:658) Although Ruch's statement is not as precise as might be desired, and despite the ambiguity of the phrase "solid subject matter," the statement does indicate the relative effectiveness of the problem-solving method, a concept on which there is some agreement.

The Progressive Education Association made a continuing study covering a period of eight years. Its results demonstrated at almost all comparison points that, among the students included in the study, the college or university performance of graduates of high schools where curriculum variations emphasized the problem-solving method was as good as or better than the performance of graduates of high schools where curriculum emphasis was traditional. Among the relevant comparison points at which the graduates of high schools using the problem-solving method were superior are:

1. They "earned a slightly higher total grade average."
2. They "were more often judged to possess a high degree of intellectual curiosity and drive."
3. They "were more often judged to be precise, systematic, and objective in their thinking."
4. They "more often demonstrated a high degree of resourcefulness in meeting new situations." (1:111-112)

According to a report on the problems approach in social studies published by the National Council for the Social Studies, "most studies which have compared the problems approach with other forms of curricular organization claim not only that problem solving is more motivational but also that it brings about improved attitudes and the command of more basic skills." (13:33)

Risk viewed optimistically the value of problem-solving method in the area of transfer of training. He said that "training in method of attacking problems should have considerable transfer value." (23:453) Clyde E. Burns, in his doctoral dissertation, wrote that "transfer is accomplished to a greater extent when learning comes through a process of meaningful problem-solving." (4:54) Dressel and his colleagues, however, were not certain regarding the broad application or transfer of scientific method to other courses and to life outside of class. (11:45)

Generalizing on research on transfer, Stephen Corey commented that the amount of transfer is a function of similarities perceived by the learner in (1) content similarity, and (2) method similarity. (6:65-66) Examination of problem-solving method in terms of these two criteria shows the obvious strength in method similarity because it has broad application.

Problem-solving method can contribute to content similarity if the problems tackled in instructional programs and the content the problems embrace are selected with attention to the common denominators of the learners' developmental needs and every-day (in-and-out-of-school) living. Significant gains in transfer then would be likely to occur because similar problems or content would be met.

It seems reasonable from summarizing the claims of strength in problem-solving method cited so far, to assume that this method not only can improve problem-solving abilities; but also that its results can be equal to or better than those of other methods in the areas of retention, transfer, acquisition of factual material, basic skills, motivation, and attitudes.

A most significant strength of problem-solving method can now be stated. Since each of the foregoing terms refers to some aspect of learning, problem-solving method is practically synonymous with learning. The idea that problem-solving method is a superior method of learning is at the heart of Dewey's educational philosophy.[2]

The Wellingtons suggested additional related benefits to be derived from emphasis upon problem-solving method. Two of them are increased understanding of one's self and of others, and faith in one's ability to solve problems. (29:31)

Problem solving as a method of teaching and of learning has further strength in that it is in harmony with the field theory of learning, a psychological theory which has come to the front in recent decades. J. M. Gwynn believed learning by insight is central to the field theory of learning, and that problem-solving method is the best approach for gaining insights. "If this theory of learning is accepted," he said, "teachers will understand clearly why certain educational leaders insist upon setting up problems or activities for children to solve." (17:63-64)

In describing the nature of the field theory, George Hartmann said:

> The field theory in its original and most universal meaning refers not primarily to a special system of psychology, but to a comprehensive world view.
> . . . .
> All events in nature--and this statement plainly includes psychological and educational phenomena--always occur within some field, big or little, whose

---

[2]In 1961, Hullfish and Smith published a book treating educational philosophy in which the authors acknowledged their indebtedness to Dewey and Boyd H. Bode. The book's title is Reflective Thinking: The Method of Education. (19)

> properties and structure explain the localized occurrence that it embraces and simultaneously permit increased control over it. (18:165, 166)

After mentioning a wide difference of opinions among the major exponents of the field theory, Harold Alberty noted three of its characteristics.

> First of all, the total situation in which learning takes place becomes important, for learning becomes a process of continuous interaction between the organism and environment.
> . . . .
> Second, the emphasis shifts from mechanical to insightful behavior.
> . . . .
> Third, and perhaps the most important, the theory places more emphasis upon the learner as a dynamic whole who is capable of acting in terms of goals which serve as a means of giving direction to the process of a continuous reorganization of the field. . . . (2:67)

Problem-solving method as described in this chapter seems to be in harmony with these characteristics and hence with the field theory of learning. This harmony can be recognized as a strength of the problem-solving method.

It should be made clear that other psychological concepts and theories of learning--for example, the stimulus-response theory perfected by the behaviorists--have made contributions to the understanding of problem-solving phenomenon. They have been inadequate, however, when compared with contributions made by field theorists. In Brownell's opinion, both in "their experimental research and in their theoretical discussions, field psychologists have been much more practically helpful than have exponents of connectionism and conditioning." (3:422)

Among scholars who have attempted to identify features of common agreement within the varieties of points of view regarding theories of learning are Alberty, Gwynn, Reid, Schmuller, Thorpe, and Watson. (2:64-83; 17:65; 22:25; 27:449-464; 28:253-257) The points of agreement identified by Alberty are:

1. Learning is an active process which involves the dynamic interaction of the learner and his environment.
2. Learning is most effective when the learner is motivated by goals which are intrinsic to the activity.
3. The most significant type of learning in a democratic society is characterized by reflective thinking, rather than by mechanical habit formation.
4. When problems are of common concern, group thinking is the most effective approach to learning.
5. Skills, appreciations, and understandings are most effectively developed as a unified whole rather than each in isolation from the others.
6. Transfer of training is most effective when the learning situation is so organized as to facilitate generalization and the recognition of relationships.
7. The development and modification of attitudes is a problem of learning which has great significance for the future of our democratic society. (2:64-83)

Examination of Alberty's list shows that it leans strongly toward the field theory of learning. It seems fair to infer that problem-solving method is in agreement with his list of general principles of learning theory. This agreement should be considered to be a definite strength of problem-solving method.

Conditions of Educative Experience

This section is devoted to defining what is meant by effective or educative learning experiences, identifying the role of intelligence, and indicating the duty of the educator in designing and guiding educative learning experiences.

Fundamental to a discussion of educative experience is the concept of growth. Growth is characteristic of living things, being continuous and ongoing. Human growth implies both deficiency and potential to develop. A growing human being should be developing increasing ability to cope with his environment. Such growth by individuals is the continual development, reconstruction, and refinement of appropriate behavior, amounting to the forming of habits. The meaning of habits is not restricted to automatic responses; it considers also a measure of effective intelligence capable of giving conscious direction toward goals, and capable of revising behavior when established patterns become inadequate. (7:62) In addition, motor skills, attitudes, and cognitive abilities, particularly in the realm of reflective thinking, are included. The reduction of some behavior to automatic level is an important function of growth, as is the development of intelligence, the essential free agent capable of defining and redefining direction.

Although growth is marked by the development of habits capable of self-revision and direction, not all habit development of this kind is growth in a true sense. Some habits lead to a stifling of further growth. They hinder rather than promote conditions suitable for further development; they sometimes even lead to dead ends. A youth whose training has led him to an attitude of thinking the showing of affection to another is sissy or unmanly may be hampered seriously in establishing positive, healthy growth conditions in his present and future family life. His inability to communicate may cause minor misunderstanding to develop which may hinder his opportunity for further growth. Growth as habit development should be concerned with habits capable of contribution to the further growth of the individual. Growth should lead to more growth; this is a key concept.

To promote this concept of growth, education should create a desire for continued growth and supply the means for making the desire effective in fact. (7:62)

Return now to a direct consideration of educative experience. Experiences are the means by which growth takes place; the means by which the objectives of education are achieved. Thus, if one assumes that growth is education, then education and growth are the results of experience. It is not implied that experience is something separate from education and growth, but that they are parts of an organic unit--as two sides of a coin are related. The unity of education, growth, and experience was made clear by Dewey when he wrote "that amid all uncertainties there is one permanent frame of reference: namely, the organic connection between education and personal experience. . . ." (8:12)

Experience and education are not necessarily directly connected, however, because not all experience is educative in a positive sense. All experience does not contribute significantly to growth. For instance, the preparation and presentation of an oral report by a student in an industrial arts class may be an educative or mis-educative experience. There may be positive elements, such as kindled interests, developed while preparing the report. There may be negative effects because an occurrence of a personally embarrassing incident during class presentation may restrict growth and result in future avoidance of group presentations. Skillful guidance by a teacher, however, can make it possible for discouragements to be converted into educative experiences.

Dewey stressed the relationship between the educative and mis-educative when he wrote:

> The belief that all genuine education comes about through experience does not mean that all experiences are genuinely or equally educative. Experience and education cannot be directly equated with each other. For some experiences are mis-educative. (8:13)

He then differentiated between the two when he said "any experience is mis-educative that has the effect of arresting or distorting the growth of further experience." (8:13)

To understand fully the concept of educative experience, the role of intelligence, and the duty of the educator, it is necessary to explore experience in more detail: to establish general criteria of educative experience.

Experience is both active and passive. (7:163) It includes the active element of trying or doing something to or with something, acting upon something. Directly connected is a passive element which designates a return wave of consequences resulting from the previous active element. Thus, an activity alone does not qualify as educative experience. The activity must be followed by a return wave of consequences. Further, the individual must be personally conscious of the consequences and of their significance. There must be feedback that is realized and incorporated within the individual in the form of new or revised insights. Thus, experience is reconstructed.

To illustrate the active and passive elements, focus attention on a student whose objective it is to join two pieces of heavy steel together by arc welding. The active portion of his experience is represented by welding the pieces together followed by his testing of the weld. Striking the metal a heavy blow with a hammer he breaks open the weld and discovers a technical failure. The student's examination of the broken weld to explain its inadequacies furnishes him excellent opportunity for feed-back of consequences. By hypothesizing about the causes of the poor weld and by corrected action based on his hypotheses, the student is furnished with the bases for learning and for continuation of the active-passive cycle until an adequate weld is effected. Through this kind of interaction of the active and passive phases of experience, insight into the relationship of means and consequences or ends is gained. Growth of ability to predict and guide means toward desired consequences is promoted.

Frequently, the phrase "learning by doing" is heard. Unfortunately, only the active phase of experience is suggested by the words. Much misunderstanding could be avoided if the phrase could be altered somehow to imply with equal emphasis the passive phase of experience. School experiences that are labeled activity programs--and these include industrial arts--have long emphasized learning by doing as the main plank in their platform. Even though this plank has been a chief strength it also has been a mark of their shortcomings. Failure to understand and to provide adequately for the passive element of experience has seriously hampered the effectiveness of activity programs.

Dewey's comment upon the active and passive phases of experience was: "(1) Experience is primarily an active-passive affair; . . . (2) the measure of the value of an experience lies in the perception of relationships or continuities to which it leads up." (7:164)

Continuation of a quest to understand the nature of educative experience leads to consideration of the principles of continuity and interaction. Continuity of experience, as a criterion for distinguishing between the educative and mis-educative, means that present experience should be regarded as continuous with the past and future, that it is inextricably connected with both. It is part of an ongoing stream of interaction of individual with environment. Educative experience should not be a disjointed, atomistic affair carried on in segments. A considerable amount of school instruction is organized into pint-sized "handi-pak" units dispensed at separate times and with little consideration to their relationship to past or future experiences.

The principle of continuity in experience is closely related to the primary criterion of an educative experience, that of adequate provision for enhancing further growth and learning. An experience which leads to a blind alley is not a genuine learning experience.

Continuity also changes in some degree "the objective conditions under which experiences are had." (8:34) For example, development of the ability to communicate graphically by interpreting and making intelligible working drawings, changes the conditions under which a person encounters such experiences as designing and constructing physical articles.

Coupled with the concept of continuity is that of interaction. Together they have been described as the "longitudinal and lateral aspects of experience." (8:42) Interaction is transaction between the individual and other persons and things, an interplay of the individual with his environment. When interaction is combined with continuity, the warp and woof of experience is affected; for it requires the threads of both directions to create the cloth of experience.

A sobering thought for educators, as suggested by the concept of interaction of individual with environment, is that school environment should be realistic. Formal education is taking place within the walls of school buildings where surroundings may not be realistic. A traditional school, for example, may be fairly devoid of instructional materials. It may rely chiefly on textbooks as sources of information with which students interact. How much better it might be for learners to interact with realistic environment. Students learning how products are mass produced could be helped by a visit to a factory. Learning how milk is processed could be enhanced by a visit to a dairy. Fortunately, much has been done in many school buildings to furnish learners with realistic instructional materials which substitute for the real things, thereby reducing the separation between school experiences and experiences outside the school.

The role of reflective thinking in the educative experience is particularly vivid in the active-passive concept. If learning is to take place, reflective thinking, must be present in the return wave of consequences resulting from action. It also must be present when consequences are predicted before judgments are made upon which to base action. Reflective thinking makes possible discovery of detailed relationships and it leads to insightful behavior, an improvement upon trial and error attempts to select means for achieving ends. Also, reflection can control impulsive behavior and can cause the individual to attempt to convert it into purposeful behavior. In perspective, ". . . <u>thinking is the method of an educative experience</u>." (19:251)

Reflection in educative experience "is the discernment of the relation between what we try to do and what happens in consequence. No experience having a meaning is possible without some element of thought." (7:169)

In review, educative experience comprises the following components:

It leads to further growth.

It provides for intelligent management of ends and means.

It is continuous with the past and the future.

It includes interaction between the individual and environment.

It is made up of both active and passive experience.

It depends upon reflective thinking.

The teacher who aspires to guide the learning of students in educative experience is faced with a complex task. He should be a student of educative experience, constantly attempting to improve his understanding of its principles, becoming increasingly sensitive in discerning the mis-educative as well as the educative.

The conditions of environment which are conducive to shaping effective experience should be the subject of intensive study and research. Dewey stressed this responsibility of the teacher. "Above all," he wrote, "they should know how to utilize the surroundings, physical and social, that exist so as to extract from them all that they have to contribute to building up experiences that are worthwhile." (7:35)

It is the duty of an educator, because of his training and maturity, to evaluate the experiences in which the young are engaged, and to judge between educative and mis-educative experiences. A teacher should use the wisdom of his maturity, training, and experience to guide the immature toward the most productive or educative experiences possible. In final analysis, the objective of educative experience is development of the individual's ability to guide his own ongoing experience in truly educative channels.

Summary

Problem solving as a method of teaching and learning was examined in this chapter. Method was described and its strengths cited. The intimate relationship of method and objective was shown by an explanation of the ends-means continuum. The relationship of method and subject matter, as well as method and technique, was defined and amplifed. The conditions of educative experience were developed as a prelude to the identification of principles for improving problem-solving abilities.

Bibliography

1. Aikin, Wilford M. The Story of the Eight Year Study, with Conclusions. Vol. I of Adventure in American Education. New York: Harper & Brothers, 1942.

2. Alberty, Harold B. Reorganizing the High-School Curriculum. New York: Macmillan Co., 1953.

3. Brownell, William A. "Problem Solving," The Psychology of Learning. Forty-first Yearbook of the National Society for the Study of Education, Part II. Chicago: University of Chicago Press, 1942.

4. Burns, Clyde E. "A Study of the Use of the Problem Solving Approach in Industrial Arts Programs in Florida Secondary Schools." Unpublished Ed. D. dissertation, School of Education, Florida State University, 1952.

5. Cook, Lloyd A., and Cook, Elaine F. A Sociological Approach to Education. New York: McGraw-Hill Book Co., 1950.

6. Corey, Stephen M. "Psychological Foundations of General Education," General Education. Fifty-first Yearbook of the National Society for the Study of Education, Part I. Chicago: University of Chicago Press, 1952.

7. Dewey, John. Democracy and Education: an Introduction to the Philosophy of Education. New York: Macmillan Co., 1928.

8. ________. Experience and Education. New York: Macmillan Co., 1938.

9. ________. How We Think: a Restatement of the Relation of Reflective Thinking to the Educative Process. Boston: D. C. Heath, 1933.

10. ________. Theory of Valuation. Vol. II, No. 4 of International Encyclopedia of Unified Science. Edited by Otto Neurath, assisted by Rudolf Carnap, and Charles W. Morris. Chicago: University of Chicago Press, 1939.

11. Dressel, Paul L., and Others. "How the Individual Learns Science," Rethinking Science Education. Fifty-ninth Yearbook of the National Society for the Study of Education, Part I. Chicago: University of Chicago Press, 1960.

12. ________. "Improving College Teaching," Basic College Quarterly, V (Spring, 1960).

13. Fersh, George L. (ed.) The Problems Approach and the Social Studies. ("National Council for the Social Studies: Curriculum Series No. 9"). Washington, D. C.: National Council for the Social Studies, 1955.

14. Fuzak, John A. "Analysis of Developments to Determine Implications for Industrial Arts," Industrial Arts Teacher, XVII (November-December, 1957).

15. ________. "Reflective Thinking as an Aim in Industrial Arts," Education, LXV (June, 1945).

16. Goldstein, Philip. How To Do An Experiment. New York: Harcourt, Brace, 1957.

17. Gwynn, John Minor. Curriculum Principles and Social Trends. New York: Macmillan Co., 1950.

18. Hartmann, George W. "The Field Theory of Learning and its Educational Consequences," The Psychology of Learning. Forty-first Yearbook of the National Society for the Study of Education, Part II. Chicago: University of Chicago Press, 1942.

19. Hullfish, Gordon, and Smith, Philip. Reflective Thinking: The Method of Education. New York: Dodd, Mead, 1961.

20. Knight, Stanford S., and Michelson, John M. "Problem vs. Subject," The Clearing House, XXIV (September, 1949).

21. Micheels, William J., and Sommers, Wesley S. The Minnesota Plan for Industrial Arts Teacher Education. Bloomington, Ill.: McKnight and McKnight Publishing Co., 1958.

22. Reid, Chandos. "Instructional Materials and Problem-Centered Teaching," Teachers College Record, LII (October, 1950).

23. Risk, Thomas M. Principles and Practices of Teaching in Secondary Schools. New York: American Book Co., 1947.

24. Ruch, Floyd L. Psychology and Life. Chicago: Scott, Foresman, 1948.

25. Russell, David H. Children's Thinking. Boston: Ginn, 1956.

26. Thorndike, Robert L. "How Children Learn the Principles and Techniques of Problem Solving," Learning and Instruction. Forty-ninth Yearbook of the National Society for the Study of Education, Part I. Chicago: University of Chicago Press, 1950.

27. Thorpe, Louis P., Schmuller, A. M. Contemporary Theories of Learning; with Applications to Education and Psycology. New York: Ronald Press Co., 1954.

28. Watson, Gordon. "What Psychology Can Feel Sure About?" Teachers College Record, LXI (February, 1960).

29. Wellington, Burleigh, and Wellington, Jean. Teaching for Critical Thinking; with Emphasis on Secondary Education. New York: McGraw-Hill Book Co., 1960.

CHAPTER IV

PRINCIPLES FOR IMPROVING PROBLEM-SOLVING ABILITIES FROM PHILOSOPHERS DEWEY AND KILPATRICK

This chapter presents and summarizes principles for improving problem-solving ability selected from pertinent works of John Dewey, and supplemented by William H. Kilpatrick's Foundations of Method. Works by both men were examined, and those yielding material clearly germane to problem-solving ability were searched thoroughly for specific concepts which constituted principles.[1] Some of these concepts were directly applicable as principles; others were less direct, yet pertinent when their implications were developed.

The chief criterion for selection of material was its relevance to two questions: What should a teacher know and be able to do to design and conduct learning experiences for the improvement of student problem-solving abilities? Is there a concept here that can be used by a teacher to implement the improvement of problem-solving abilities? After principles were identified, they were screened to eliminate those which had meaning for education in general: for almost

---

[1]See Chapter VI, pp. 189-192, for definition of principles.

all kinds of teaching-learning situations. A statement that reduction of distractions will aid in problem solving, for example, was excluded because of its relevance to almost any teaching situation. Exceptions were made, however, because many general principles are particularly pertinent to improving problem-solving abilities.

The principles to be dealt with in this chapter have direct bearing on the designing and conducting of learning experiences for improving student problem-solving abilities. They are thought to be of general significance for teachers of any school subject. It is not intended that only principles which for some reason might be considered particularly appropriate for industrial arts instruction be included. Illustrations used to clarify principles, however, generally will be drawn from the field of industrial arts.

Development of Problem-Solving Abilities is Indirect

Dewey clearly indicated he thought that teaching of problem-solving ability should be indirect; that improvement of student problem-solving ability is best accomplished when the teacher regulates conditions to guide improvement.

"The teacher may devise special exercises intended to train thinking directly," Dewey wrote,

> but when these wrong conditions exist, special exercises are doomed to be futile. The training of thought can be attained only by regulating the causes that evoke and guide it. (3:56-57)

> The problem of method in forming habits of reflective thought is the problem of establishing conditions that will arouse and guide curiosity; of setting up the connections in things experienced that will on later occasions promote the flow of suggestions, create problems and purposes that will favor consecutiveness in the succession of ideas. (3:56)

Kilpatrick wrote, regarding stimulation of thinking, "we do not directly convey thought. We stir it." (4:229) These statements help to establish the underlying principle that the improvement of student problem-solving abilities is promoted indirectly by the teachers providing a favorable climate.

This principle should not be confused with one stated earlier: The improvement of student problem-solving abilities requires conscious teacher planning.[2] The earlier statement emphasized the need for teachers consciously to plan for the improvement of student problem-solving abilities as an objective or goal within the design of teaching-learning activities. The principle being considered in this chapter is that teacher planning must center on creating conditions of environment favorable to the stimulation of reflective thinking or problem solving. In this sense, the teacher's approach is indirect, not frontal; his planning efforts are direct. For example, telling a youngster that giving half-truths and exaggerating are poor practices is

---

[2]Chapter II, p. 35.

not generally as effective as setting up conditions which will make it possible for him to experience or observe the consequences of such practices.

For additional clarification, contrast the idea of expecting a student to memorize the formal steps of problem solving--a direct approach--with the idea of focusing the student's attention on vitally interesting problems which will motivate his efforts to solve them--the indirect approach. Another illustration: Suppose a teacher returning written work to a student tells him there are several misspelled words in one of the paragraphs. If the teacher points out the words and writes down their correct spelling for the student, he is teaching directly. If, however, the teacher stops short of giving the correct spelling and provides the student with a list of several references where the correct spelling can be found, and he then tries to arouse in the student enough anxiety to motivate him to remedy his own problem, the teacher is using the indirect approach.

The immediately ensuing principles are assembled under the five phases of problem solving: source and nature of problems, problem definition, occurrence of suggestions for development into problem solution, development of hypotheses by reasoning, and testing hypotheses by experimentation. They are followed by principles which, because of their general nature, do not lend themselves to inclusion under any particular phase of problem solving. It should be emphasized that the principles considered under the five phases should not be regarded as restricted in their pertinence only to the phase under which they are gathered.

Source and Nature of Problems

A major proposition developed in this study is that problem-solving ability can best be improved through experience in solving problems.[3] The choice of problems selected for improving this ability can be a critical one. It is the purpose of this section to identify principles relevant to their nature and source.

Problems Should Grow Out of Student Experience

Problems should grow out of actual situations and out of the personal experience of students. (3:99) Dewey said "a genuine problem develops within this situation [experience] as a simulus to thought." (2:192)

A youngster becomes interested, for example, in raising white mice at home. He soon may realize that he must provide the kind of environmental conditions that will satisfy the needs of the animals without offending the sensibilities of his own family. The mice will require an enclosure or cage to serve as housing. Out of this circumstance

---

[3]Chapter III, p. 55.

emerges a problem that is vital and real to the child. It should lead to an analysis of the problem to determine the criteria for an adequate enclosure and of its procurement through purchase or construction.

A teacher who is attempting, at the junior high school level, to develop concepts of the relationship of power and speed in performing work would do well to use the bicycle as an illustration rather than a lift winch. A problem about how a bicycle can be modified to enable its rider to climb steep hills or to develop speed on level ground is likely to draw on actual student experience.

Problems Should be Vital and Real

If problems are vital and real in the life of a student, they should produce in him a feeling of difficulty or need which should help to furnish an impetus necessary for him to carry them through to completion. Problems that do not emerge from a student's actual experience create a necessity for the teacher to provide artificial, external motivation which could reduce the educative value of the problems.

A problem, to have definite educative potential, must create in the student a felt difficulty or need. It is the duty of the teacher to design problems that create felt difficulties recognizable to the student. The teacher contributes to the sharpening and intensifying of the felt difficulty by arousing a degree of anxiety in the student. "The best . . . preparation needed," Dewey observed, "is arousal to a perception of something that needs explanation, something unexpected, puzzling, peculiar." (3:268) A skillfully phrased and timed question may be sufficient to focus student attention upon a problem. A teacher may observe that a student preparing to glue together wooden parts of a water ski is about to choose a non-waterproof adhesive. By asking what kind of conditions the glue and wood eventually will be subjected to, the teacher may be able to arouse in the student a degree of anxiety necessary to produce a vital, real felt difficulty: concern about what kind of glue will withstand water.

The degree of anxiety necessary to carry a student along from one educative experience to another often develops spontaneously. Yet it should be stated as a principle that the teacher should do all that is reasonably possible to make sure a felt difficulty or degree of anxiety is present in educative experiences.

The Problem Selected Should Be the Student's

Kilpatrick has made it clear he thinks problems should be selected by the student, not the teacher, because "the more fully the pupil feels the problem and determines to solve it, the more fully do set and readiness, satisfaction and annoyance, help him to succeed and help him learn from what he does." (4:246)

Teacher Should Guide Students in Identifying Problems

The teacher has definite responsibilities in the selection of problems because he is the appointed leader of a group.

> In reality the teacher is the intellectual leader of a social group. He is a leader, not in virtue of official position, but because of wider and deeper knowledge and matured experience. The supposition that the principle of freedom confers liberty upon the pupils, but that the teacher is outside its range and must abdicate all leadership is merely silly. (3: 273-274)

The teacher, because his maturity, knowledge, and experience give him perspective superior to that of his students, has the duty to guide the process of identifying and selecting problems. "Since the purpose [problem] to be carried out must come directly or indirectly, from somewhere in the environment [experience], denial to the teacher of the power to propose it," Dewey wrote, "merely substitutes accidental contact with some other person or scene for the intelligent planning of the very individual who, if he has a right to be a teacher at all, has the best knowledge of the needs and possibilities of the members of the group of which he is a part." (3:274) It is the responsibility of the teacher to guide both individual students and groups in the selection of problems.

Both Students and Teacher Should be Involved in the Identification and Selection of Problems

The preceding statements by Kilpatrick and Dewey regarding selection of problems appear to be in conflict. Kilpatrick indicated he thought problems should be selected by the student; Dewey said the teacher should exert leadership in the selection process. Actually, there is no conflict. Neither prefers activities that are externally assigned without consideration of student experience. Both men think such activities have poor potential for being genuinely adopted by students because the problems are likely to be remote from the reality of the students' background of experience. Teachers should not direct and dominate a classroom to force exclusion of students from all but a very minor role, for students must be intimately involved in activities if they are to have the direction and impetus necessary for follow-through. Students, however, should not be free to pick and choose whatever suits their fancy, with the teacher standing by merely observing. It is desirable that both students and teacher be fully involved in the identification and selection of problems.

Problems which are primarily initiated by the teacher should show recognition of the student's background of experience; and they should be carefully introduced to stimulate the student's acceptance of them as though they were his own. If they are not so accepted they will fall short of their intended function. Problems suggested by students should be carefully considered by the teacher for potential, and then either put into use or altered and developed into suitable activities.

Problems Should Include a Balancing of the Old and the New

Problems selected for improving problem solving abilities should show a balance of the old and the new, the familiar and the strange. Dewey observed that "the best thinking occurs when the easy and the difficult are duly proportioned to each other. The easy and the familiar are equivalents, as are the strange and the difficult." (3: 290)

> The old, the near, the accustomed, is not that to which but with which we attend; it does not furnish the material of a problem, but of its solution.
> . . . .
> The nearer at hand furnishes the point of approach and the available resources. (3:290)

"We should, at the outset of any new experience in learning, make much of what is already familiar." But in caution, we should remember that "too much that is easy gives no ground for inquiry." (3:290)

The strange in the balance between the new and the old furnishes the unknown element which constitutes a genuine problem situation. Without the unknown there would be no problem to be solved. "The more remote supplies the stimulus and the motive." Yet, "too much that is hard [strange] renders inquiry hopeless." (3:290) Finally,

> the necessity of the interaction of the near and the far follows directly from the nature of thinking. Where there is thought, something present suggests and indicates something absent. Accordingly, unless the familiar is presented under conditions that are in some respect unusual, there is no jog to thinking; no demand is made upon hunting out something new and different. And if the subject presented is totally strange, there is no basis upon which it may suggest anything serviceable for its comprehension. (3:290)

<u>Problems Should Provide for a Balancing Interaction of Concrete and Abstract Thinking</u>

This principle is closely related to the previous one. Dewey has explained the meaning of concrete and abstract by relating them to direct and near, and to indirect and remote. Terms which convey their meaning directly with no need of translation, such as table, shoe, and spoon are concrete. "The meaning of some terms and things, however, is grasped only by first calling to mind more familiar things and then tracing out connections between them and what we do not understand." (3:220)

Educative activities should make much of the familiar or concrete and they should include an increasing amount of the abstract. "The educative activities of childhood," Dewey wrote,

> should be so arranged that the activity creates a demand for attention to matters that have only an indirect and intellectual connection with the original activity. To take an instance to which reference has already been made, the direct interest in carpentering

> or shop work should gradually pass into an interest in geometric and mechanical problems. (3:226)

Students who generally think concretely should be encouraged to deepen their thinking through interest in the abstract; and those whose thinking generally is in the abstract should have a variety of opportunities to apply their ideas to the concrete.

> Methods that, in developing abstract intellectual abilities, weaken habits of practical or concrete thinking fall as much short of the educational ideal as do the methods that, in cultivating ability to plan, to invent, to arrange, to forecast, fail to secure some delight in thinking, irrespective of practical consequences. (3:228)

Problems May Have Their Source in School Activities

School activities afford fertile ground for the development of problem-solving abilities. They provide conditions from which real problems can arise naturally. They offer intellectual possibilities, because they may "be used for presenting typical problems to be solved by personal reflection and experimentation." (3:217) Dewey emphasized "the need of active pursuits, involving the use of material to accomplish purposes, if there are to be situations which normally generate problems occasioning thoughtful inquiry." (2:184) Activities such as gardening, dramatics, field trips, writing, speaking, drawing, sewing, games, and building with tools and materials can provide numerous real problem situations for stimulating thinking and acting on new insights. (2:230-231)

The strength of activities is that "they give the pupils something to do, not something to learn, and the doing is of such a nature as to demand thinking, or the intentional noting of connections." (2:181) The implication here is that giving students something to learn that has little connection with means-consequence relationships is relatively impotent in the development of their problem-solving abilities. Activities give students an opportunity to do something from which can emerge problems, thinking, and learning.

The ordering of thought comes through ordering of action. "The majority of people," Dewey said, "probably all of their lives, attain to some ordering of thought through ordering of action." (3:49)

> Adults normally carry on some occupation, profession, pursuit; and this furnishes the stabilizing axis about which their knowledge, their beliefs, and their habits of reaching and testing conclusions are organized. (3:49)

School activities can serve the same function in ordering of thought.

At the center of educative experience and problem solving is the gaining of insights and meanings. These insights do not occur because one merely wishes them to; they occur through development of means-consequences relationships. Dewey emphasized this thought when he wrote:

> We may sum up by stating that things gain meaning when they are used as means to bring about consequences (or as means to prevent the occurence of undesired consequences), or as standing for consequences for which we have to discover means. The relation of means-consequences is the center and heart of all understanding. (3:146)

Activities, to be of value in improving problem-solving abilities, must provide for intelligent purposing of means towards ends.

One of the chief causes of failure in developing problem-solving abilities in school, according to Dewey, is "neglecting to set up conditions for active use as a means in bringing consequences to pass--neglecting to provide projects that call out the inventiveness and ingenuity of pupils in proposing aims to realize, or finding means to realize consequences already thought of." (3:147) Activities that have promise for developing problem-solving abilities are those which provide needed opportunity for the gaining of insights and meanings through purposeful and intelligent management of means and ends. This criterion, if applied to the many possible school activities, may help teachers select, develop, and guide those activities having the greatest potential for improving problem-solving abilities.

School activities are fully qualified to offer potential educative experience as defined in Chapter III.[4]

---

[4] Chapter III, p. 79.

They provide for the emergence of numerous real problem situations, ordering of thought through action, and management of means-consequence relationships.

Activities offer potential for development of problem-solving abilities; however, taking part in them offers students no assurance they will develop those abilities. "There is indeed no magic by which mere physical activity or deft manipulation will secure intellectual results." (3:217) The activities themselves are not intellectual. They help furnish the conditions from which necessity for intelligence can emerge.

The teacher's responsibility, then, is to discover and arrange activities which are most favorable for developing problem-solving abilities. Dewey suggested that, in general, activities should be adapted to the maturity level of students; and that activities should "have the maximum of influence in forming habits of acute observation and of consecutive inference." (3:52)

Because many such problem situations emerge from activities the following six principles derived from Dewey's comments on school activities are germane to the identification of problem situations having high potential for improving problem-solving abilities.

First, activities should have objectives that are known and reachable. Lack of known objectives can lead to aimless play. An objective or goal is needed to guide the course of an activity. Students "must conceive ends and consequences with sufficient definiteness to guide their actions by them. . . ." (3:213)

Second, teachers should avoid externally assigned or dictated activities because they may be low in student personal commitment and intrinsic satisfaction.

> Activity carried on under conditions of external pressure or coercion is not carried on for any significance attached to the doing. The course of action is not intrinsically satisfying; it is mere means for avoiding some penalty, or gaining some reward at its conclusion. (2:240)

Third, "there must be more actual material, more <u>stuff</u>, more appliance, and more opportunities for doing things." Dewey observed, after comparing the difference between in-school and out-of-school conditions which seem to produce problem situations, "reflection on this striking contrast will throw light upon the question of how far customary school conditions supply a context of experience in which problems naturally suggest themselves." (2:183) He said that when students are engaged in actually doing things with materials and appliances, including reflection on what problems may arise, "children's inquiries are spontaneous and numerous, and the proposals of solutions advanced, varied, and ingenious." (2:183) A consequence of students not working with materials and appliances which generate real problems in a real context is that problems are less likely to be the students'; they are more likely to be teacher-assigned from external sources.

Fourth, "activities which follow definite prescription and dictation or which reproduce without modification ready-made models, may give muscular dexterity, but they do not require the perception and elaboration of ends." (2: 213)

> A child, like an adult, may make or follow something following the dictation of others, working mechanically from oral or printed instructions or stereotyped blueprints. There is then next to no thought; his activity is not truly reflective. (3:212)

Probably a chief reason why many teachers tend toward prescription of this sort of procedure is their desire to avoid possibilities of student errors. This is an unfortunate concern, because the possibility of making mistakes is necessary if students are to learn the limits of their powers. Furthermore, errors can be highly educative.

Fifth, maximum gain will be realized when the content of physical or intellectual activities has been subjected to a minimum of pre-perfection or predigestion by the teacher or other authority over students. This is not to indicate that some prearranging may be undesirable, depending in degree upon student maturation. The more the raw material or subject matter has been subjected to predigestion, however, the smaller its potential becomes as an activity for developing problem-solving abilities. Dewey said it is most objectionable for teachers or books to supply ready-made solutions instead of giving to students materials that they can adapt and apply for themselves to the questions at hand. (2:185) "Only by starting with crude material and subjecting it to purposeful handling will he [the student] gain the intelligence embodied in finished material." (2: 232) A simple illustration of this point is the practice by some industrial arts teachers of pre-cutting materials (making little more of them than do-it-yourself kits) for students to use in construction activities. All the parts need is assembling and finishing. Quite obviously, such a teaching method reduces the potential of the activities for the development of problem-solving abilities.

Sixth, activities should be concerned with wholes. "Intellectually the existence of a whole depends upon a concern for interest; it is qualitative, the completeness of appeal made by a situation." (2:232) Wholes then, are outlined by the purpose and appeal of a situation. It is a common occurrence in educational practice to find much student effort being guided into exercises which are separated from purpose. The idea that students in industrial arts classes should have practice in basic tool operations separate from application in carrying out a major purpose is illustrative of this. Practice in squaring a board, in making a series of common wood joints, or in soldering that is isolated from its application is effort expended independently of "the purposes of discovery and testing which alone give it meaning. It is argued that pupils must know <u>how</u> to use tools before they attack actual making,--assuming that pupils cannot learn how in the process of making." (2:232) Activities carried out in such an isolated manner, however, are not concerned with wholes. Activities that place skills, attitudes, and knowledge in immediate context with overall purposes are so concerned.

Regarding the preceding material which has dealt with the nature and source of genuine problems and their significant potential for the development of problem-solving abilities, two questions posed by Dewey are pertinent. They are helpful for discriminating between mock and genuine problems.

> Is the experience a personal thing of such a nature as inherently to stimulate and direct observation of the connections involved, and to lead to inference and its testing? Or is it imposed from without, and is the pupil's problem simply to meet external requirement? (2:232)

Problem Definition

Earlier in this chapter--in the sub-section, "Problems Should Be Vital and Real"--it was discussed at some length that a major condition for developing problem situations is the presence of a felt need or an indeterminant and unsettled condition. Although there may be awareness of difficulty which is emotional and vague, realization that a perplexing situation needs inquiry constitutes the necessary conditions for a problem situation to develop. "The first result of evocation of inquiry is that the situation is taken, adjudged, to be problematic. To see that a situation requires inquiry is the initial step of inquiry." (1:119)

The transition from felt need to definition of a problem is much the same as the transition from a condition of indeterminacy to one that is relatively determinate. "To find out what the problem and problems are which a problematic situation presents to be inquired into, is to be well along in inquiry." (1:119)

Problems are Defined From Situations

A situation and a problem do not appear simultaneously; the problem develops out of a situation. "There is not at first a situation and a problem, much less a problem and no situation." (3:108) This has significance when teacher-assigned problems are examined critically. When the teacher bluntly assigns a problem to his students he is in reality bypassing the situation, or at least collapsing the situation and problem into one. The teacher should attempt to capitalize on students' past experience or provide rich experiential situations that he can use to skillfully point-up problematic situations which can be developed.

At a school, youngsters may park and secure their bicycles in any way possible. This can result in a jammed pile of vehicles that are frequently damaged and that give a cluttered appearance to the school grounds. Such a situation may lead to a felt dissatisfaction regarding the condition, producing a problematic situation. A teacher might make inquiry of his class about bicycle damage and school appearance; or an awareness of unsatisfactory conditions might develop spontaneously among the students. From this situation a problem might emerge naturally. It might progress through a number of phases resulting, as the best solution to the problem, in the building of bicycle racks by a group of boys in an industrial arts class. This problem situation is in signal contrast to an industrial arts teacher merely assigning to his students the task of building bicycle racks for the school.

Definition Is Aided by Examination of Constituent Conditions

The task of converting the indeterminate problematic situation into a more determinate, defined problem requires some degree of intellectualizing. "This conversion is effected by noting more definitely the conditions that constitute the trouble and cause the stopping of action." (3: 109) He indicated the place of reflective thinking in defining the problem. His statement suggests to the teacher that helping students search for the conditions causing a problematic situation is beneficial in defining problems and hence in promoting problem-solving abilities.

Direct Action Should Be Postponed

A principle with meaning throughout the problem-solving process is that direct action should be delayed so reflective thinking may occur to guide subsequent action. Dewey wrote that "some inhibition of direct action is necessary to the condition of hesitation and delay that is essential to thinking." (3:108)

Immediate action which occurs before the problem has been well defined may result in poorly expended effort. Inhibition of impulsive, direct action is necessary to make sure that the problem has been reasonably well defined. Yet, impulse toward action supplies an element which is valuable as a driving force. What is needed is impulse balanced by reason.

Definition Is Aided by Experimentation

In relatively simple problems, the felt needs and their definition may in fact be merged or inseparable, occurring practically simultaneously with no great amount of thinking. Yet, in more complex problems considerable ingenuity and experimentation may be essential to pin down the problem explicitly. The educator should be aware of the range of activity which is appropriately needed to define problems, and to gauge his efforts to stimulate definition accordingly. Insistence that students write down conditions of definition may be desirable in some complex situations but it could be distinctly deadening and undesirable in many.

Quality of Definition Sets Stage for Remainder of Inquiry

Accompanying the successful definition of a problem is a description of its solution; that is, specifications for an acceptable solution, not the route for its accomplishment. Dewey wrote that "problem and solution stand out completely at the same time." (3:108) For example, a student has a summer job caring for lawns and gardens in his part of town. It is necessary that he take with him, from place to place, various lawn and garden tools. He decides to use a bicycle trailer to carry them. His problem becomes one of procuring a suitable bicycle trailer. Some thought is directed to the problem of determining the functions or qualities of a trailer suitable for the task, in this way describing the problem in more detail. His listing of specific functions also can be his description of an adequate solution. The list includes the specification of the solution. Thus, in this sense, the problem and its solution stand out together although the actual route for reaching the solution is yet incomplete.

This fact has significance for the educator because the definition of a problem and accompanying criteria for its solution set the conditions for the remainder of the inquiry. The criteria become "the end in view that guides [thinking]." (4:68) They become a yardstick or standard which gives unity to subsequent efforts. Dewey pointed out:

> The way in which the problem is conceived decides what specific suggestions are entertained and which are dismissed; what data are selected and which rejected; it is the criterion for relevancy and irrelevancy of hypotheses. (1:120)

It would be well for teachers to encourage thoroughness in students' problem definitions.

Occurrence of Suggestions for Development Into Problem Solutions

Between the definition of the problem and the existence of relevant hypotheses is a gap which somehow must be spanned. It involves a leap from what is known to the unknown; from a problem to a suggestion that provides the nucleus to be developed into tentative hypotheses.

Suggestions, which are clues or seeds to be developed into ideas and hypotheses, seem to be produced as a person searches out and examines relevant data surrounding a problem. The exploration of these suggestions "stimulates the performance of new observations and the collection of new data." (3:166) Examination of the new data may produce additional suggestions, thus continuing the interplay between data and suggestions. An additional factor in the occurrence of suggestions seems to be the availability of relevant past experiences. As latent concepts are recalled to consciousness, suggestions occur.

Teachers Can Facilitate Suggestion Occurrence

Dewey wrote:

> The first suggestion occurs spontaneously; it comes to mind automatically; it springs up; it "pops," as we have said, "into the mind"; it flashes upon us. There is no direct control of its occurrence; the idea just comes or it does not come; that is about all that can be said. (3:109)

> . . . having of ideas is not so much something we do, as it is something that happens to us. (3:42)

Dewey's observations would seem to eliminate any hope that a teacher may control the occurrence of suggestions, but it does not. It is but a statement that the actual tripping of the trigger occurs in a mysterious way over which there seems to be little control. It is not at variance with his observations about the essential function of searching the situation for relevant data in producing suggestions. "A possible relevant solution is then suggested by the determination of factual conditions which are secured by observation." (1:121) Dewey suggested that conditions antecedent to the occurrence of suggestions can be controlled to a degree.

In writing about the spontaneity of suggestions, he said that though "we cannot make ourselves have ideas or not have them . . . we can put ourselves or be put by others into situations where we are likely to have sensations and ideas in worthwhile ways. (3:41)

Situations with potential for eliciting suggestions, as noted by Dewey, depend;

> . . . on the state of culture and knowledge at the time; upon the discernment and experience and native genius of the individual; upon his recent activities;

> to some extent upon chance; for many of the most pregnant inventions and discoveries have come about almost accidentally, although these happy accidents never happen except to persons especially prepared by interest and prior thought. (3:169)

It seems reasonable that teachers can exert considerable influence in the regulation of conditions favorable for eliciting suggestions. Students' attention should be directed to their prior experience, activity, or thought, both immediate and remote, because "that portion of . . . present experience which is like that of prior experience will call up or suggest something or quality connected with it which was present in the total previous experience." (3:41) Further, "when suggestions occur to us, they come to us as functions of our past experience and not of our present will and intention." (3:42) The background of experience a person carries with him seems to be of primary importance. Teachers should direct their efforts toward providing experiences which will help create in their students rich experiential backgrounds.

Absorption is practically essential to the production of suggestions. It is necessary that a person saturate himself with the constituent data surrounding a situation, for suggestion "rarely occurs except to a mind that has previously steeped itself consciously in material relating to its question." (3:248) Hence, the teacher should encourage the problem solver to saturate himself with information surrounding the problem situation.

Encourage Inventory of Fixed Conditions

Early in the process of attempting to produce suggestions, one should turn to an examination of the situation for conditions that are relatively fixed. "The first step then is to search out the constituents of a given situation which, as constituents, are settled." (1:120)

Driving along the street, a man may notice his automobile is jerking. A quick survey may reveal to him that the road surface is smooth; that no tire is flat; that the jerking continues in any gear position, and that vibration continues when the car is not in motion with the engine running. These conditions suggest that the trouble probably is in the engine. Such a survey of the conditions surrounding a situation helps to localize the problem, making it more manageable and determinate.

Encourage Experience in Procurement of Data Through a Number of Avenues

Relevant data and information can be gained through a variety of routes including observation, experimentation, reference to authoritative written or spoken information, and memory or experience. Teachers should provide their students with the opportunity to gain experience in the use of these methods.

Developing ability and know-how in observation can be encouraged by using it as a tool in meaningful, natural problem situations. "In normal development, specific analytic observations are originally connected . . . with the imperative need for noting means and ends in carrying on activities." (3:249)

Dewey believed that ability in observation is not developed through the various teacher-designed exercises which are carried on out of context. He wrote:

> Training by isolated exercises leaves no deposit, leads nowhere; and even the technical skill acquired has little radiating power or transferable value. Criticisms made upon the training of observation, on the ground that many persons cannot correctly reproduce the forms and arrangement of the figures on the face of their watches, misses the point, because persons do not look at a watch to find out whether four o'clock is indicated by IIII or by IV, but to find out what time it is, and if observation decides this fact, noting other details is irrelevant and a waste of time.
>
> . . . .
>
> What often makes observation in school intellectually ineffective is . . . that it is carried on without a sense of a problem that it helps define and solve. (3:250)

In order that training of observation be sharpened through problem experiences, teachers should provide conditions in which observation is an active process of exploration, has an element of suspense, and is scientific in nature. (3:252-256)

What has been noted here about teacher-designed exercises in improving observation abilities has broad application for improvement in other problem-solving abilities. Exercise carried on as an end in itself is unsound. It should be closely connected with a purpose; it should be the means toward achieving ends; and the over-all purpose should be visible to the student. A course of study in industrial arts house planning (architectural drawing) which begins with extended assignments in line, lettering, and symbol practice is to be questioned on the basis of its remoteness from application and need. It is separated from purpose. Special practice in the drawing of an architectural symbol would be appropriate if a student found difficulty in forming it intelligibly and with reasonable neatness when he needed to communicate meaning in a drawing.

The above reference to a scientific kind of observation leads to the idea that production of data can be augmented by experimentation. In the example of the rough running automobile, the difficulty was identified as probably engine trouble. Raising the hood, the driver might see an engine shaking on its mounts. This datum, gained through observation, could suggest that a cylinder is misfiring. Experimentation introduced at this point could produce data which would verify or reject the driver's suggestions. Thus, by shorting out all spark plugs individually until one is located which does not increase idle roughness, he experimentally provides himself with data useful in verification or rejection of suggestions and in resetting the stage for the flow of more suggestions.

Authority or testimony are represented primarily by written materials and teachers or other persons who pass on their knowledge. "In spite of the great extension of direct observation in our schools, the vast bulk of educational subject matter is derived from other sources--from textbook, lecture and viva voice interchange." (3:256)

Dewey raised a crucial question when he asked: "How shall we treat subject matter that is supplied by textbook and teacher so that it shall rank as material of reflective inquiry, not as ready-made intellectual pablum to be accepted and swallowed." (3:257) In answering his own question, he made three recommendations: first, that "communicated material should be needed . . . it should be such as cannot readily be attained by personal observation;" second, that "material should be supplied by way of stimulus, not with dogmatic finality and rigidity;" third, and fully as important as the others, that "the material furnished by way of information should be relevant to a question that is vital in the student's own experience." He said further "that material furnished by communication must be such as to enter into some existing system or organization of experience," that teaching of "subject matter that does not fit into an interest already stirring in the student's own experience or that is not presented in such a way as to arouse a problem is worse than useless for intellectual purposes." (3:257-258) Thus, information communicated from sources outside a student's experience is necessary; it should be supplied as a stimulus; and it should be relevant to the student's experience in order to contribute constructively to his data collection.

There is a need for abundant instructional materials in the form of reference sources, apparatus, tools, and other physical materials to be used in the production of suggestions through data collection.

Encourage Alteration Between Broad and Narrow Concentration on Data

The problem solver should be encouraged to alternate between a broad, general absorbing of information and a sharp, localized concentration on a few pertinent facts. "Problems become definite, and suggested explanations significant by an alternation between a wide and loose soaking in of relevant facts and a minutely accurate study of a few selected facts." (3:225) Broad observation helps to orient the problem solver and to give him his bearings in relationship to the total situation. It also provides him with pertinent information in context. Localized concentration narrows the problem for him and identifies the conditions for experimental testing.

Allow Time for Incubation

A component in the production of suggestions which teachers should recognize and provide for students is time for incubation. It is not unusual for persons to find themselves stopped when attempting to see relationships in a group of data or conditions. After a period of attention to other matters, suggestions may occur to them with little difficulty. Dewey described the phenomenon as incubation.

> It is a common experience that after prolonged preoccupation with an intellectual topic, the mind ceases to function readily. . . . This condition is a warning to turn, as far as conscious attention and reflection are concerned, to something else. Then after the mind has ceased to be intent on the problem . . . a period of incubation sets in. Material rearranges itself; facts and principles fall into place, what was confused becomes bright and clear; the mixed-up becomes orderly, often to such an extent that the problems are essentially solved. (3:284)

Problem Redefinition May Start the Flow of Pertinent Suggestions

The way a problem is defined may not remain fixed throughout the experience of solving the problem because subsequent experience may reveal necessity for alteration. Teachers should regard redefinition of problems among their students as an expected and desirable occurrence, and should encourage it to bring into play crucial factors previously overlooked or underestimated. Redefinition may serve to start the flow of a new group of pertinent suggestions.

There seem to be no rigid rules for providing conditions which call up suggestions. Suggestions and data emerge in interaction with each other. "Observation of facts and suggested meanings or ideas arise and develop in correspondence with each other." (1:121) They seem to reinforce or interact with each other as do two boys tossing a baseball back and forth. The driver's observation of possible causes for the rough running automobile, mentioned previously, suggested engine trouble. This suggestion caused the driver's subsequent observation of the engine to furnish him data that precipitated occurrence of further suggestions --a misfiring cylinder. Suggestion and information interplay in the emergence of relevant suggestions for development into tentative hypotheses.

Development of Hypotheses by Reasoning

The suggestions which occur to an individual are subject to development into ideas or hypotheses. As insight is gained, the suggestion is modified and expanded. "In this fashion the suggestion becomes a definite supposition, or stated more technically, an hypothesis." (3:110) Actually, suggestions become precipitators of activity which may or may not lead to their elaboration into full blown hypotheses.

Dewey's distinction between suggestion, idea, and hypothesis follows. Suggestion, as explained in the previous section, is that flash of insight which occurs with regard to a solution for a problem situation. It is untested. An idea is one step beyond suggestion in development, having been identified as having promise.

> Every idea originates as a suggestion, but not every suggestion is an idea. The suggestion becomes an

> idea when it is examined with reference to its functional fitness; its capacity as a means of resolving a given situation. (1:122)

Ideas that are subjected to reflective examination in terms of their consequences and that show promise, even though they may be tentative and provisional, are called hypotheses. Further exploration and reflective thinking which establishes higher degree of certainty, increasingly relaxes tentativeness. The three terms can be placed along a continuum ranging from highly tentative to probably correct.

The forming of hypotheses from suggestions is primarily a matter of reflective thinking or reasoning supported by pertinent data gained primarily from observation, experimentation, reference to authority, and past experience. The implication and possible consequences of suggestions are developed and checked by reasoning. Examination of their consequences may cause them to be rejected for further development as hypotheses. "Suggestions at first seemingly remote and wild are frequently so transformed by being elaborated into what follows from them as to become apt and fruitful." (1:112) The importance of reasoning in the development of suggestions into hypotheses was pointed up by Dewey when he wrote that "reasoning has the same effect upon suggested solution that more intimate and extensive observation has upon the original trouble." (1:112)

The role of reason was further amplified by Dewey. "To perfect this hypothesis," he wrote, "existing conditions have to be carefully scrutinized and the implications of the hypothesis developed--an operation called reasoning." (2: 177) Reasoning should be coupled with the continuous need for information or data about conditions surrounding a situation.

> Observations pertain to what exists in nature. They constitute the facts, and these facts both regulate the formation of suggestions, ideas, hypotheses, and test their probable value as indications of solutions. (3:111)

> The data arouse suggestions, and only by reference to specific data can we pass upon the appropriateness of the suggestions. (2:186)

It is an interaction of data and reason which seems to develop suggestions into pertinent hypotheses.

> Reflection is an operation in which facts on one side and meaning on the other are elicited through constant interaction with each other. Each newly discovered fact develops, tests, and modifies an idea, and every new idea and new shade of an idea lead to further inquiry, which brings to light new facts, modifying our understanding of facts previously observed. (3:165)

It can be stated as a principle that the teacher should encourage an alternation between gathering of data and formation of ideas. When the problem solver finds his progress in reasoning blocked, he should turn to absorbing information which may precipitate new and clarify old ideas. On the other hand, concentrated attention on a promising idea, a tentative hypothesis, may give needed direction to the problem solver's search for verifying or relevant data.

The teacher attempting to guide students in the development of suggestions into hypotheses should be aware of a number of principles that should be helpful.

Expand Consequences of an Idea Before Accepting It

The implications of an idea should be developed before they are accepted or rejected as leading to a tentative hypothesis. Any tendency to leap to the acceptance of a suggestion as a solution worthy of being acted upon should be held off pending examination of the consequences of its acceptance. "When a suggested meaning is immediately accepted, inquiry is cut short." (1:123) Acceptance of a suggestion in its first form, Dewey observed, is prevented by looking into it more thoroughly. "Conjectures that seem plausible at first sight are often found unfit or even absurd when their full consequences are traced out." (3:112)

Encourage Attitudes of Tentativeness

When a student's attitude of tentativeness in hypothesis development is encouraged, "he proceeds to act upon it [a suggestion] tentatively rather than decisively. That is, he treats it as a guiding idea, a working hypothesis, and is lead to make more observations." (3:110)

Use Hypotheses as Guides

One way to systematize the development of hypotheses is to use them as guides. A problem solver can search the field for evidence when a promising idea is at hand. He then can support or reject the evidence. "He strives to convert them [facts] into just those data which will test the suggestions that occur to mind." (3:169) The driver's suggestion that his rough running engine was the result of a faulty sparkplug could be used as a guide. He then could search the situation for verifying evidence.

Build Rich Experiential Background

The ability to reason through the consequences of an idea is partly dependent upon the prior experience of an individual. A rich experiential background makes it possible for a person to carry on fairly long chains of reasoning. "And this depends not only upon the prior experience and special education of the individual who is carrying on the inquiry, but also upon the state of culture and science of the age and place." (3:111) There is a need for truly educative experiences, as described in Chapter III, to create a rich background of meaningful, interrelated experience. One of the best ways a teacher can promote in his students the ability to think through the implications of suggestions, ideas and hypotheses is to provide the kind of experiences which develop awareness of interrelationships, a background of meanings and concepts which are interrelated rather than isolated and disjointed.

Encourage Focusing of Attention on One Thing at a Time

Reasoning should be focused upon a central topic or object. One does not begin a reasoning process with a number of facts of equal importance. Some one item normally claims attentive thought and becomes the center for departure. The driver of the automobile with the misfiring cylinder first thought through the idea that fuel might not be reaching the combustion chamber. He then considered the idea that no electrical spark was reaching the fuel mixture. Reflecting upon the implications of each of these ideas separately in view of observed facts and previous knowledge is more effective than attempting to handle both simultaneously. Teachers should encourage students to explore the implication of each idea separately. Exploration of relationships of ideas should follow. This does not mean that relationships of ideas should not be dealt with; but that attention should be focused on one main idea at a time, rather than on a group of ideas equal in importance.

> In reaching a generalization the mind does not naturally begin with objects a, b, c, d, and try to find the respect in which they agree. It begins with a single object or situation, more or less vague and inchoate in meaning, and makes excursions to other objects in order to render understanding of the central object consistent and clear. (3:272)

Ask Student to Defend His Hypotheses

Dewey indicated that making the student justify his suggestions stimulates better reasoning.

> He should be held responsible for working out mentally every suggested principle so as to show what he means by it, how it bears upon the facts at hand, and how the facts bear upon it. (3:271)

Testing the Hypothesis by Experimentation

"The concluding phase [of problem solving] is some kind of testing by overt action to give experimental corroboration, or verification, of the conjectural idea." (3:113-114) Dewey urged "that the student should have opportunity and occasion to test his ideas by application, to make their meaning clear and to discover for himself their validity." (2:192)

The previous phase of problem solving and this one can hardly be separated. Their relationship was described by Dewey.

> Reasoning shows that *if* the *idea* be adopted, certain consequences follow. So far the conclusion is hypothetical or conditional. . . . Sometimes direct observation furnishes corroboration. . . . In other cases, . . . experiment is required: that is, *conditions are deliberately arranged in accord with the requirements of an idea or hypotheses to see whether the results theoretically indicated by the idea actually occur*. (3:114)

> An hypothesis, once suggested and entertained, is developed . . . until it receives a form in which it can instigate and direct an experiment that will disclose precisely those conditions which have the maximum possible force in determining whether the hypothesis should be accepted or rejected. (1:124)

> . . . every complete set of reflective inquiry makes provision for experimentation--for testing suggested and accepted principles. (3:188)

The foregoing statements suggest three principles for teachers to consider when designing and conducting learning experiences for improving problem-solving abilities.

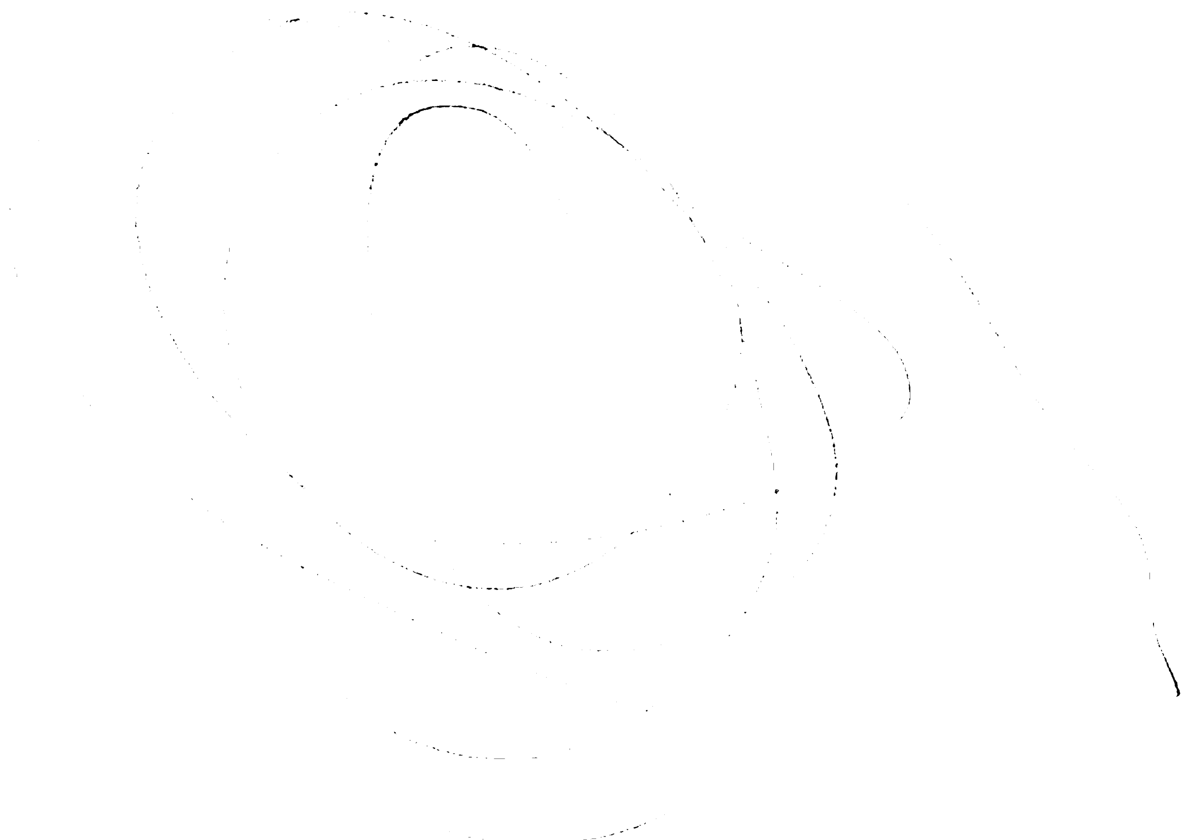
First, students should be encouraged whenever possible to verify their reasonably tested hypotheses by experimental testing. Second, students should be acquainted with some of the procedures and practices for testing and experimenting which have been developed; for example, the experimental variation of conditions and the collection of a multitude of cases. Third, schools should be equipped with facilities for the developing and testing of hypotheses through actual experience.

> Where schools are equipped with laboratories, shops, and gardens, where dramatization, plays, and games are freely used, opportunities exist for reproducing situations of life, and for acquiring and applying information and ideas in the carrying forward of progressive experiences. (2:190)

<u>All Hypotheses Need Not Be Experimentally Verified</u>

Although Dewey recommended experimental verification of hypotheses as the final test, (3:183-184) he did say that it is not always possible to experimentally test every hypothesis. (3:97, 107) Some hypotheses are only reasonably or logically verifiable. (5:505-506) For example, classes working on solutions to such social problems as federal aid to public and private elementary education would find it difficult to move beyond the thoughtful anticipation of consequences of their proposed hypotheses.

It may also be reasoned that, with increased background of experience and consequent improved maturity in judgment, a person would be increasingly able to test



accurately the implications of hypotheses by reasoning, without necessity of experimental verification. Postponing payment of the household utility bills to stretch the budget would bring consequences which should not need experimental verification after one experience of this sort.

Rejection of Hypotheses Can Be Educative

Frequently, favorite hypotheses fail the test of experimental and practical application. The teacher, however, should be quick to recognize that this may be just as educative as success in the testing of hypotheses.

> But a great advantage of possession of the habit of reflective activity is that failure is not mere failure. It is instructive. The person who really thinks learns quite as much from his failures as from his successes. . . . Nothing shows the trained thinker better than the use he makes of his errors and mistakes. (3:114)

Verified Hypotheses Should Be Applied

Dewey raised a question as to the existence in reflective thinking of a sixth phase which yields a principle important to this study. The question is whether "a look into the future, a forecast, an anticipation, or a prediction" should be considered as an additional phase in the process, (3:117) whether the reasonably and experimentally verified hypotheses should be applied in connection with or in prediction of future events. (3:117) He proposed that the very process of reflective thinking has future reference built into it. "As a matter of fact," he wrote, "every intellectual suggestion or idea is anticipatory of some possible future experience, while the final solution gives a definite set toward the future." (3:117) Nevertheless, he noted that "in some cases, the future reference may be so important as to require special elaboration." (3:117)

The question of whether future reference should be regarded as a distinct phase of problem solving is not as important as the fact that it is a vital principle to be recognized in the development of problem-solving abilities. The teacher should encourage students to connect their reasonably and experimentally tested hypotheses, regarded as relatively determinate solutions, to the prediction of future events. An industrial arts student, for example, who has worked out a solution through reasoning and experimentation for securely fastening wooden legs to a coffee table should be encouraged to predict its appropriateness in like situations.

Periodic Appraisal Is Productive

Dewey stressed the importance of periodic appraisal of on-going experience to summarize net accomplishment. (3:189) New bearings can be taken, products can be inventoried, techniques of process generalized, relationships realized, and new problems identified. Periodic appraisal has special importance in the development of problem-solving abilities, particularly with reference to improving techniques of process. Teachers should encourage and provide students with opportunities for recapitulation of experiences to identify successful and unsuccessful practices used in arriving at solutions. These opportunities could be brought about by teachers' questions designed to focus students' attention on various phases of process through referring to specific incidents in their experience with problems.

General Considerations

The preceding principles were assembled around Dewey's five phases of reflective thinking because it seemed that their meaning could be made clear by so doing; but there may be danger that the reader will interpret their application narrowly. It therefore bears repeating that the principles considered in the preceding pages, although assembled under the five phases of Dewey's reflective thinking, should not be regarded as restricted in their pertinence only to the phase under which they are gathered. The principle, for example, of allowing time for absorption and incubation of suggestions has relevance of some degree to most of the phases.

The principles which follow did not lend themselves to inclusion in a particular phase of problem solving because of their general nature.

Do Not Require Following of Model Process

It should be clear to teachers that problem solving does not slavishly follow models of form. This idea, stated as a principle for establishing conditions conducive to the improvement of problem-solving abilities, is that teachers should not require or expect student thinking to follow a model of form. Illustrative of this principle is the frequency with which persons, after grappling with a problem for some time, are compelled to redefine it with more precision. According to Dewey,

> The five phases, terminals, or functions of thought, that we have noted do not follow one another in a set order. On the contrary, each step in genuine thinking does something to perfect the formation of a suggestion and promote its change into a leading idea or directive hypotheses. It does something to promote the location and definition of the problem. Each improvement in the idea leads to new observations that yield new facts or data and help the mind judge more accurately the relevancy of facts already at hand. The elaboration of the hypotheses does not wait until the problem has been defined and adequate hypothesis has been arrived at, it may come at any intermediate time. And as we have seen, any particular overt test need not be final; it may be introductory to new observations and new suggestions, according to what happens in consequence of it. (3:115)
>
> In conclusion, we point out that the five phases of reflection that have been described represent only in outline the indispensable traits of reflective thinking. In practice, two of them may telescope, some of them may be passed over hurriedly, and the burden of reaching a conclusion may fall mainly on a single phase, which will then require a seemingly disproprotionate development. No set rules can be laid down on such matters. . . . (3:116)

The principle accommodates the idea that some phases may be telescoped, some passed over lightly, and that one phase may be expanded far out of proportion to the others. Thus, one problem may well engage a student in much experimental verification of an easily formulated hypothesis, while another problem may demand concentrating upon the manufacturing of suggestions by examining conditions surrounding the problem. In classroom practice it would be a mistake to demand that students follow precisely and show proof of having followed model problem-solving steps. Industrial arts teachers would be in error to expect and require students to solve product-design and construction problems according to a model of orderly problem solving. It would be highly questionable for a teacher to compel a boy with interest in designing and building a cage for housing white mice to follow precisely the orderly model of form.

Student Attention on Formal Process Should Not Come First

The question may arise whether students should be made conscious of formal steps when they solve problems, whether they consciously should have to "note and formulate these various phases as a means of intellectual control." (3:283) Dewey said he thought such practice is contrary to the spirit of inquiry. "*After* the instructor has once provided the conditions most likely to call out and direct thinking," he wrote, "the student's subsequent activity, while conscious of ends and means, may be unconscious with respect to his own personal attitudes and procedures." (3:283)

> The common assumption that, unless the pupil from the outset consciously recognizes and explicitly states the method logically implied in the result he is to reach, he will have no method and his mind will work confusedly . . . is fallacious. It is equally erroneous to believe that, if he accompanies his performance with conscious statement of some form of procedure . . . his mind is safeguarded and strengthened. As a matter of fact, the gradual, largely unconscious, development of logical attitude and habit comes first. A conscious setting forth of method logically adapted for reaching an end is possible only after the result has first been reached by unconscious and tentative methods. (3:128-129)

Discussing the conscious and unconscious, Dewey recommended that the teacher avoid the use of methods that tend to pry into the familiar, the usual, the automatic, the unconscious simply for the sake of utilizing them. (3:282)

He indicated, however, several situations in which there is a distinct usefulness for conscious attention to process. He wrote:

> In cases of unusual perplexity or repeated error it will help if conscious attention goes back to such causes as lie in the attitudes and processes of the learner. (3:283)

> When things have gone wrong, it is . . . a wise practice to review the methods by which the unwise decision was reached, and see where the misstep was made. (3:116)

> Conscious setting forth of the method is valuable when a review of the method that achieved success in a given case will throw light upon a new similar case. (3:129)

> When a topic is to be clinched so that knowledge of it will carry over and be an effective resource in further topics, conscious summarizing and organization are imperative. (3:282)

In summary, attempts to focus conscious attention on formal process should not come first. They should occur when there is a need to locate a difficulty causing error or unusual perplexity, to identify previously successful methods, or to clinch topics so that knowledge of them will carry over and become effective resources in additional topics.

Child Himself Should Take the Steps

Kilpatrick recommended that a child should take his own steps in solving problems, that a teacher should not take them for him. "As far as is feasible," Kilpatrick said, "the child should consciously take each step himself, but the teacher may step in to save from defeat. In such a case he helps best by helping the child to help himself." (4:247)

It is interesting to note that Kilpatrick suggested the teacher should save the child from defeat. This point of view appears to be in direct conflict with Dewey's opinion that failure to solve a problem may be thoroughly educative. (3:114) It can be speculated, however, that Kilpatrick could have been in agreement with Dewey, for he may have meant to communicate the idea that the teacher should step in to save the child from a mis-educative experience by converting it into an educative one.

Avoid Artificial Time Limits

Students engaged in problem solving should not be pressured by artificial time limits. "Exacting prompt and speedy responses from them, is not conducive to building up a reflective habit of mind." (3:272)

Skillful Questioning Helps Create Needed Conditions

Dewey explained that he thought teacher questioning, as a valuable technique in stimulating student thinking, is an art that should recognize several principles. (3:266-267) They are paraphrased as follows:

1. Questions should motivate the student dealing with new problems to use material already learned. Hence, the teacher could ask the student floundering in a new problem situation to inventory those facts and principles already known to him. Questions could be chosen which would focus student attention on connections between something known and something new. In a problem situation it might become necessary to reduce the rpm of a drill press by moving the V-belt drive to a different set of steps on the cone pulleys. Assuming the students know the meaning of circumference, they can be asked which adjacent step of the driver pulley has greater circumference, which has less,

and why. This can be followed by a question about which pulley step will consume the most V-belt in one revolution.

2. Questions should direct the student to subject matter rather than to the teacher's aim. Thus, a "guessing bee" as to what the teacher is really after can be avoided. Insistence on the "right" answer (the teacher's answer) in situations where a number of answers might be plausible is poor practice. It would be better to focus questions as objectively as possible on the conditions or subject matter of the problem situation. The industrial arts teacher who involves students in planning laboratory equipment maintenance programs often guides student discussion with questions and comments aimed at bringing the group to "discover" the teacher's personally predetermined plans. Questions should be directed toward identification of the conditions which make up a problem situation, such as machinery causing trouble because it is in disrepair, or because it needs regular lubrication.

3. Questions should develop the subject continually by setting up a situation inclusive enough to have movement within it. They should build for the student a large, inclusive situation within which there can be movement from one point to another, and within which meaningful relationships can be seen. Incompatible with this principle are questions which, when answered, dispose of a matter with a tone of finality so that other matters may not be considered.

The teacher, discussing with the student interested in designing a cage for white mice, might ask the boy, as he is considering the service access opening: "Why do you need access through the enclosure? What things will you need to do through this entrance in order to care for the needs of the animals?"

4. Questions should periodically require a survey and review of subject matter that has been covered to extract its net meaning, and to help students gather together and hold what is significant. Questions should be asked not primarily for answers, but to stimulate thought. Instead of asking, "What kind of wood screws are used in wooden boat building?", it would be better to ask, "Why are brass screws used in boat building?"

The Teacher Should Maintain a Balance Between Furnishing Too Much and Too Little Information

A crucial factor in stimulating student thinking is teacher behavior with regard to furnishing information and directions in problem situations. Too little teacher involvement can be as disastrous as too much. "The practical problem of the teacher is to preserve a balance between so little showing and telling as to fail to stimulate reflection and so much as to choke thought." (3:270) Not only can too little aid lead to failure to stimulate thought, but also to discouragement and aimless activity. Conversely, too much teacher supplied information can fail to provide conditions conducive to evoking student thinking. Dewey suggested that the teacher "should enter especially at the critical junctures where the experience of pupils is too limited to supply just the material needed." (3:270) It is important that the teacher maintain a balance between furnishing too much and too little information.

Information Acquired Through Problem Solving Is Meaningful

Information, to have lasting value and to be available when needed, should be acquired in connection with problems. Stated negatively, information encountered outside of its use is not as likely to be available when needed again. "The assumption," said Dewey, "that information that has been accumulated apart from use in the recognition and solution of a problem may later on be, at will, freely employed by thought is quite false." (3:64) Although it is possible for many students to store up a great fund of information and data, it is of little real value except as "nice to know" unless it is available for use. To be useful, knowledge should have meaning in terms of connections and relationships. Meaning is furnished through intelligent use of reason, through use in solving problems.

Trial and Error and Insight

The question may be posed as to whether trial and error method of solving problems should be encouraged. Dewey recognized "cut and try" method as performing a needed function. "We never get wholly beyond the trial and error situation," he observed. "Our most elaborate and rationally consistent thought has to be tried in the world and thereby tried out. (2:177) Here trial and error is used purposefully to test the results of thinking through to some hypothesis.

Trial and error technique used without guiding purpose and used at random is not to be highly regarded, however, because it lacks reasoning and is fairly inefficient. Connections are discovered quite by accident. Trial and error technique with a guiding purpose to which activities continually can be related does have a place in problem solving. This method may lead the student to recognize the relationship of cause to effect, but not necessarily to recognize why relationships exist. Although "we see <u>that</u> a certain way of acting and a certain consequence are connected, we do not see <u>how</u> they are." (2:170) The difficulty is one of seeing the details of the connection, of gaining insight into their relationships.

To extend insight into understanding of connections, "we must analyze to see just what lies between so as to bind together cause and effect, activity and consequence." (2:170) This involves reflective thinking. Trial and error may be successful in gathering information which causes insight that connections do exist; but insight and understanding of the details of the connections are gained through reflection.

In general, it can be said that purposefully directed trial and error can be useful in discovering, developing, and testing implications and consequences. Teachers, however, should discourage random trial and error that is devoid of rational direction.

Another question may be posed as to whether problems should be solved through trial and error <u>or</u> through insight. Insightful solutions to problems are more highly regarded because "the action which rests simply upon the trial and error method is at the mercy of circumstances; . . . if we know in detail upon what the results depend, we can look to see if the required conditions are there." (2:170) Dewey undoubtedly would have answered this question by pointing out that problems are solved by both trial and error <u>and</u> insight. The trial and error method can be a useful tool in gathering information which can help produce insight in conjunction with reflection. In problem solving, trial and error can be useful if it is intelligently directed, and if it leads to insightful understanding of cause and effect relationships.

Summary

The major principles in this chapter were taken from

Dewey and Kilpatrick, and developed in the belief that teachers should be aware of and act upon them when guiding the improvement of student problem-solving abilities. A list of the principles follows.

1. <u>Source and Nature of Problems</u>

   A. Identify or develop problems that emerge from actual situations in student experience. These may come from the students' background of general experience or from experiences provided by the teacher.

   B. Problems should be vital and real in the life of the student and should include a felt difficulty.

   C. It is desirable that <u>both</u> students and teachers be fully involved in the identification and selection of problems. Problems selected should be the students'. It is the responsibility of the teacher to guide in selection of problems.

   D. Problems should include a balancing of the old and the new. Without the new or strange elements there would be no problem; without the old or familiar, inquiry might be hopeless.

   E. Problems should provide for a balancing interaction of concrete and abstract thinking.

   F. School activities can furnish real potential for development of problem-solving abilities because they provide for the emergence of numerous real problem situations which require ordering of thought through action and management of means-consequence relationships. Activities in themselves may not be intellectual. They can provide the conditions from which necessity for intelligence and reasoning emerge.

G. Activities or problems should have high potential for forming habits of observation and inference.

H. To guide the course of action, activities and problems should have ends that are known and attainable.

I. Externally assigned or dictated activities and problems should be approached with caution because they may be low in personal commitment and intrinsic satisfaction.

J. Abundant opportunity for active use of materials and equipment should be provided for.

K. Activities and problems to be avoided are those which follow definite prescription and dictation, or which reproduce without modification, ready-made models. Such problems do not require intelligent perception and elaboration of ends.

L. Maximum gain should be realized when the content of activities, whether it be physical or intellectual, has been subjected to a minimum of pre-perfection by the teacher.

M. Activities and problems should be concerned with wholes. They should place skills, attitudes, and knowledge in immediate context with overall purposes.

II. Problem Definition

A. Problems are defined from situations.

B. Help students to search for the causal conditions of a problem situation.

C. Impulsive, direct action should be balanced or delayed by reflective thinking so that the problem can be reasonably well defined.

D. Definition of complex problems is aided by experimentation.

E. Insistence that students write down the conditions of definition may be desirable in some complex situations, but can be distinctly deadening and undesirable in others.

F. The quality of the definition sets the stage for the remainder of the inquiry; hence, thoroughness should be encouraged.

III. <u>Suggestion Occurrence</u>

A. Since suggestions seem to occur with the interaction of (1) developing an acquaintanceship with existing conditions in a situation and (2) past experience, the teacher should direct his efforts toward providing experiences which help create a rich experiential background, and toward encouraging the problem solver to saturate himself with information surrounding the problem situation.

B. Encourage student examination of the problem situation for relatively fixed factual conditions.

C. Experience in the procurement of data should be encouraged through a number of channels including observation, experimentation, reference to authoritative written or spoken information, and memory or past experience.

1. Development of student observation abilities is not promoted effectively through teacher-designed exercises carried on out of the context of their application to over-all purposes.

2. Provision should be made for conditions in which observation is an active process of exploration, has an element of suspense, and is scientific in nature.

3. Reference to authoritative written or spoken information which is relevant to the problem at hand should be encouraged.

4. Need is apparent for instructional materials in the form of reference books, apparatus, tools, and physical materials to be used in data collection.

D. Encourage the problem solver to alternate between a broad, general absorbing of information and a sharp, localized concentration on a few pertinent facts.

E. Time should be provided for incubation through breaks or diversions from concentrated attention on problems.

F. Problem redefinition may serve to start the flow of a new group of suggestions.

IV. Development of Hypotheses by Reasoning

A. Develop hypotheses from suggestions by encouraging alternation between gathering data and formation of ideas.

B. Encourage students to expand the implications of an idea through thoughtful examination of its consequences before accepting it.

C. Promote an attitude of tentativeness in hypothesis development.

D. Encourage students to use promising ideas as guides in hypothesis development by searching the problematic situation for evidence that will support or reject them.

E. Promote ability to think through the implications or consequences of suggestions, ideas, and hypotheses by providing the kind of experiences that develop awareness of interrelationships--a background of meanings and concepts which are interrelated, not isolated and disjointed.

F. Encourage students to explore the implications of each idea somewhat separately, leaving until later exploration of relationships to other ideas.

G. Ask students to defend their hypotheses.

V. Testing of Hypotheses by Experimentation

A. Whenever possible, encourage testing of reasonably verified hypotheses through experimentation.

B. Some hypotheses are only reasonably or logically verifiable because they are quite difficult or impossible to test experimentally. Others need not be experimentally tested because increasingly comprehensive experiential background and maturity in reflective thinking provides the individual with ability to verify hypotheses with sufficient surety through the use of reason.

C. Acquaint students with the procedures and practices of experimental testing which the culture has developed.

D. Provide students with equipment and facilities for testing hypotheses experimentally.

E. Failure of promising hypotheses to pass reasoned or experimental verification may be educative in terms of improving problem-solving abilities.

F. Encourage students to apply their reasonably and experimentally tested hypotheses in connection with or in prediction of future events.

G. Require students to undertake periodic appraisal so that new bearings may be taken, product can be inventoried, techniques or process generalized, relationships realized, and new problems identified.

VI. General Considerations

A. Improvement of problem-solving abilities is an indirect affair promoted by regulating the conditions which guide it.

B. Practice or exercise carried on as an end in itself is unsound. It should be closely connected with a purpose, as means to achieving an end, and this should be visible to the student.

C. Do not require or expect student thinking to follow rigidly models of problem-solving process. Some phases may be telescoped, some passed over lightly, and others may be expanded.

D. Teachers should not attempt to focus the student's attention on formal process at the beginning of a problem-solving situation. Conscious attention to formal process should be called upon to locate some unusual perplexity or some difficulty causing an error. Also, the student can be helped to identify previously successful methods, and to clinch topics for effective future use by giving his conscious attention to formal process.

E. The student should take his own steps in problem solving; the teacher should not take them for him.

F. Problem solvers should not be pressured by artificial time limits.

G. Questioning as a valuable technique in stimulating thinking should include the following:

1. Questions should motivate the student to use material already learned in dealing with new problems.

2. Questions should direct the student to subject matter rather than to the teacher's aim, thus avoiding a "guessing bee" as to what the teacher is really after.

3. Questions should build for the student a large, inclusive situation within which there can be movement from one point to another, and within which meaningful relationships can be seen.

4. Questions should periodically require a survey and review of subject matter that has been covered to extract new meanings and to gather together and hold what is significant.

H. Maintain a balance between furnishing too much and too little information.

I. Information, to have lasting value and to be available when needed, should be acquired in connection with problems.

J. Trial and error methods can be useful in problem solving if they are intelligently directed and if they lead to insightful understanding of cause and effect relationships.

Bibliography

1. Bernstein, Richard J. (ed.) John Dewey on Experience, Nature and Freedom: Representative Selections. New York: Liberal Arts Press, 1960.

2. Dewey, John. Democracy and Education: an Introduction to the Philosophy of Education. New York: Macmillan Co., 1928.

3. ________. How We Think: a Restatement of the Relation of Reflective Thinking to the Educative Process. Boston: D. C. Heath, 1933.

4. Kilpatrick, William H. Foundations of Method; Informal Talks on Teaching. New York: Macmillan Co., 1925.

5. Savery, William. "The Significance of Dewey's Philosophy." in The Philosophy of John Dewey. Edited by Paul A. Schilpp. 2d. ed. New York: Tudor Publishing Co., 1951.

CHAPTER V

PRINCIPLES FOR IMPROVING PROBLEM-SOLVING ABILITIES THROUGH EXPERIMENTAL RESEARCH

This chapter deals with experimental research in problem solving that has direct bearing on what a teacher can do to improve student problem-solving abilities.

The number of diversified experimental studies in the broad area of thinking and problem solving is so great as to be unwieldy for the purpose of this chapter. A choice among the studies, therefore, had to be made. Several authoritative research reviews formed the basis of the search for principles. Those here considered are by Thorndike (1950), Johnson (1955), Russell (1956), Corman (1958), Lee and Bingham (1959), Duncan (1959), and Russell (1960). Also considered are individual studies published in journals during the period 1956-1960.

The chief criterion applied to the experimental studies was their relevance to the questions: "What should the teacher know and be able to do to implement the improvement of student problem-solving abilities?" and, "Could these findings be used by a teacher directly to effect improvement of problem-solving ability?" If relevance could be seen in a research study, it seemed reasonable that it should be included here. Because of the bulk and diversity of the experimental research, however, and because of the tentativeness of most findings, because of the complex conditions inherent in such research, the relevance had to be fairly direct and clear for the study to be included here. Other criteria applied are the same as those in Chapter IV.

It was expected that a search of problem-solving research would produce a large number of experimental studies that had been carried on in real classroom situations, using typical school problems. Actually there is a scarcity of such studies. This fact was corroborated by both Corman and Russell when they said:

> It is true that direct classroom applications of the work are somewhat sparse. (8:464)

> How to develop abilities for problem solving in human affairs has been largely neglected in research. (31:656)

Russell suggested the complexity of the usual classroom problems and the school's customary emphasis on product rather than process in arriving at solutions as reasons for a paucity of educational research in problem solving. (30:252)

Most studies were carried on in special settings, and they dealt with a variety of problems, many of them synthetic. The concern of most experimental studies seems to be with the problem-solving process as a phenomenon, with the characteristics of the solver, the variations of the problem, or the production of correct solutions. Few are concerned directly with the lasting improvement of problem-solving abilities.

Experimental research on improving problem-solving abilities was found to be poorly integrated. Hence, basing firm principles on it must be approached cautiously. The research is characterized by its lack of clear delineation of variables, (8:461) great variety in problem tasks employed, disagreement on behavioral terminology, and some failure to relate data from one study to another. (10:426) As a result, findings of experimental research in the field of problem solving must be viewed as tentative and with a measure of reservation, particularly with regard to the objectives of this study.

On the other hand, despite reservations, the field is far from being devoid of pertinent material. The findings in this chapter are not as comprehensive as those in the previous one; but for the most part, the experimental evidence corroborates the principles developed in the preceding chapter.

The organization of this chapter is similar to that of the preceding one except that the phases of problem solving are reduced from five to three: namely, preparation, production, and verification. Preparation regards source of problems and problem definition. Production covers the occurrence of suggestions and their development into promising ideas. Verification deals with testing hypotheses, both through reason and by actual try-out. Some principles are assembled under each of the three phases, and they are followed by principles that are better presented free from association with any one phase of problem solving.

Preparation

The Problem Should Be the Problem Solvers

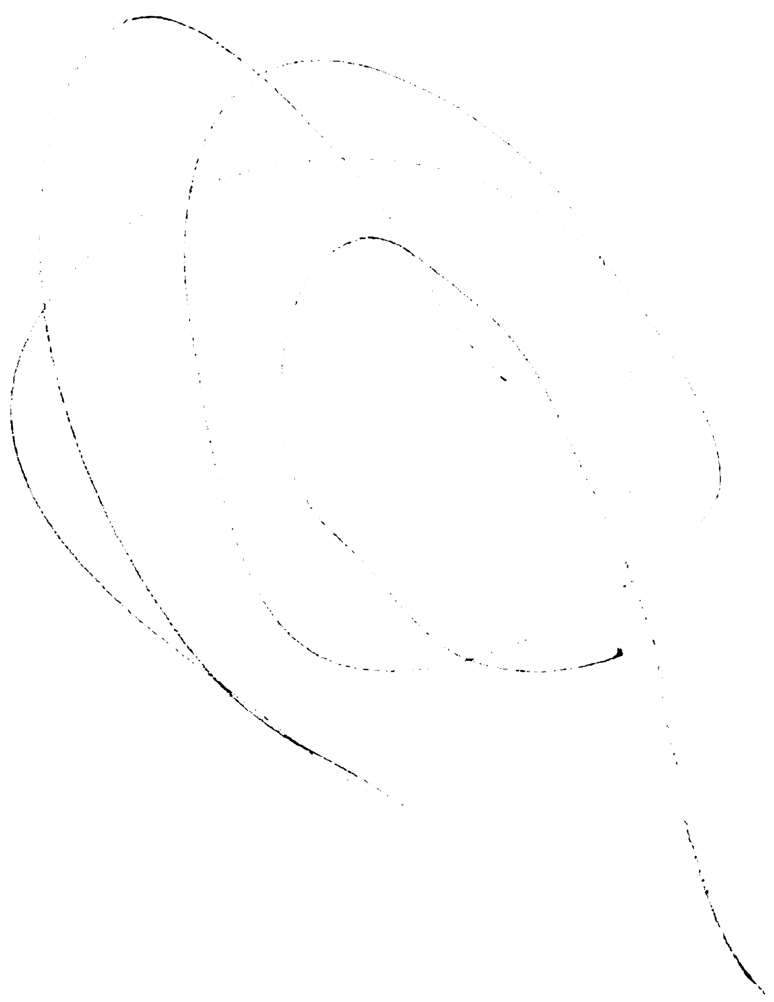
An extensive review of experimental research studies indicates that the problem solver should identify himself so closely with the problem undertaken that it becomes his own. (30:375) The problem must be recognized by its solver as having value or merit for study. Students should be encouraged to work on problems drawn from their own experience, even to face and tackle their personal problems. Guidance may be supplied by the leader or teacher in the recognition of suitable problem situations. The important condition here, because it provides the motivation necessary to follow a problem through to some sort of disposal, is that the student feel the problem is important to him, that it is closely related to his interests. The individual's and the group's levels of aspiration give clues to the kinds and complexity of problems that can be employed. (30:375) If the problems used are keyed to student interests and aspirations, they are more likely to be adopted as the student's own.

Encourage Awareness of Problems

Thorndike suggested that developing student awareness of problems can be accomplished by providing a rich and varied experiential background in question- and curiosity-provoking situations. (34:210) He encouraged an outlook on the part of educators as going beyond the limits of the traditional classroom to the world outside: to provide shops, tools and materials, to employ movies, and to sponsor special interest groups. Awareness of problems can be fostered by the attitude of the teacher toward questioning. An outlook which regards the world as a place to be investigated and understood encourages in students a questioning attitude. Conversely, admonition by the teacher that questions or problems raised be restricted to the specific assignment serves to illustrate a discouraging practice.

An Optimum Level of Anxiety Is Desirable

The traditional notion that emotion interferes with problem solving still is held despite evidence that it can be of service. (30:348) It is true that emotion can be extremely disruptive. With specific reference to the level of anxiety and its effect on problem solving, Spencer wrote in his doctoral dissertation that anxiety is closely related to problem-solving ability; that anxiety-ridden



individuals, those tending naturally toward a high level of anxiety under stress, are less accurate in problem solution under stress conditions. (34:2504-2505) Sinha and Singh found that high-anxiety subjects made more errors and took more time than did low-anxiety subjects. (32:469)

Empirical evidence clearly indicates there is such a thing as raising too much anxiety for effective problem solving. Some individuals tend toward higher levels of disruptive anxiety and learn to recognize and cope with more anxiety than others. What is needed is an optimum level of anxiety and emotional involvement for each individual--one which is neither devoid of or loaded with anxiety, one which is sufficient to bring both adequate motivation and identification. For the teacher to accomplish a healthy balance in each student is a delicate task indeed. Evidence was not found of experimental research in specific techniques for teachers.

Develop Meanings Involved in Problems

An early step in problem definition is the development of meanings. (30:375) This is particularly important in teacher-designed problems when the student may be unfamiliar with some terms or concepts that are implicitly or explicitly involved. There are several methods that can lead toward the development of meanings. Discussion could be directed toward the meanings involved. Students could be given opportunities, as in field trips, to see for themselves. When possible, as in the case of tools, materials, and machinery, students could get direct experience by manipulating them.

Encourage Careful Delimitation of What is Included in the Problem

Johnson emphasized careful discrimination of what is included in the problem and what is excluded. He suggested that the problem can be narrowed by working from either end: from what is given to what is required or from what is required to what is given. He further suggested that any graphic device for outlining or diagramming the problem situation should be helpful. (17:488)

Reduce the Problem to a Singular Goal

Efficiency in solving a problem varies inversely with the number of goals involved. (4:161) Redundant activity can be the direct result of students working toward a number of goals at the same time. This idea supports the contention that problems should be sharply defined and reduced to singleness of purpose.

Encourage Students to Redefine Goals

It is highly important to encourage the modification or redefinition of goals as problem solving progresses.

Experience brings new factors into play which can change the complexion of the problem, (30:375) as is illustrated by the interplay among various phases of problem solving.

Production

Johnson described the production phase of problem solving as being enthusiastic, fluent and provocative. He contrasted production with the preceding preparation process which he described as being deliberate, critical and serious. (17:491-492) In this description of production he was referring only to production of suggestion, not the later examination and verification through use of reasoning or testing in actual conditions when deliberateness would again be appropriate.

Encourage Ability to Shift Set

The production of problem solutions can be aided or hindered by set. Set is defined as momentary dominant response tendencies. (10:402)

Set can be helpful in that it can give continuity or thrust to a train of thought that may produce an adequate solution to a problem. When set is rigid, however, it restricts occurrence of alternative solutions. For maximum performance, a person should be flexible enough to have the ability to shift sets when necessary to consider a variety of alternatives.

A craftsman who wants to apply a protective transparent finish to the mahogany trim on his new boat may select spar varnish without consideration of other finishes because it has worked in the past. He has set toward spar varnish as the material to use on exterior surfaces. This set leads him to overlook the possibility of other, recently developed, transparent wood finishes for exterior use. On the other hand, a set based on an attitude of thoroughness can lead to an extensive search of currently available finishing materials to identify appropriate alternative solutions.

To admonish teachers to promote flexibility and to avoid rigidity of set in student problem-solving behavior is about as helpful as placing THINK posters on the classroom bulletin board. Carpenter, in his article, "Educational Significance of Studies in the Relation Between Rigidity and Problem Solving," compiled an extensive list of practices and conditions which seemed to increase mental rigidity. Selected items from his list are:

1. Personal threat.
2. A psychological set for speed.
3. Lack of preparedness in "real life" problem situations.
4. Authoritarian behavior by the teacher.
5. Lack of maturity.
6. Increased effort.
7. Massed practice.
8. Rote practice.
9. Lack of repeated orientation toward advantages of flexibility.
10. A non-varied experience in use of tools.
11. Verbal expression by subject of a low attitude toward the problem.

12. Docile behavior toward the experimenter or teacher.
13. Lack of up-to-date self evaluation.
14. Repeated punishment in a rather stable stimulus complex.
15. Teacher actions which stifle imagination through ridicule or physical threat. (7:310-311)

Allow Time for Suggestions to Occur

Fox wrote that, according to his research, increasing the allowance of time improves the quality of written problem solutions. (12:1250-1251) When the flow of solutions is blocked, the problem solver may find temporary abandonment helpful. (34:213) "Abandoning the problem when the production curve levels off," Johnson wrote, "seems to be the best technique for eliminating interferences and allowing incubation to occur." (17:492) Experimental evidence provided by Rokeach, and by Adamson and Taylor seems to support temporary abandonment as a useful technique for reducing rigidity, which is frequently the cause of blockage. (28:206-216; 3:122-126)

Exhaust All The Possibilities of an Approach

Students, to avoid flightiness, should explore thoroughly all possibilities of an approach before abandoning it for another. (17:492) Perseverance in an approach generally pays off.

Use Calculated Guesses for Precipitating Suggestions

A calculated guess made by a student on the basis of his knowledge of some facts may be useful to him as a tool for precipitating a suggestion. (17:494) This procedure amounts to choosing an answer that looks promising and trying it out in light of the facts of a given situation. If the answer does not fit it may be revised and tried again.

Verification

Encourage Development of Hypotheses Through Reasoning

Problem solvers taking part in a research project in 1957 who verbalized their solutions of a manipulative problem before carrying it out made fewer errors and required fewer trials than did students in the control group that proceeded directly to solve the problem without verbalization. (26:289-290) This result indicates that pausing and thinking through a solution in order to verbalize it improves problem solving. The result also seems to lend support to the basic principle that hypotheses should be developed or tested through reasoning before being acted upon. Thorndike contended that the "first aspect of testing hypotheses is ability to deduce by logical reasoning the consequences of the hypotheses." (34:214) A boy, for example, who wants to know if a nail is made of steel, may reason that if it is, it will be attracted to a magnet. Acting upon his reasoned hypothesis, the boy can directly verify or reject it by applying the nail to a magnetic test.

Encourage Testing of Tentative Hypotheses by Action

As an antidote to over-verbalization in problem solving, tentative hypotheses sometimes should be tested by action. (30:376) Determination of the authenticity of some problem solutions need not or cannot be tested by action. Many, however, need to be "shaken down" by the test of application, as was the case in the preceding illustration concerning the nail and magnet.

Other Considerations

Johnson offered the following techniques as aids to improving judging ability as focused on verification of hypotheses.

1. Shift contexts or points of view before reaching final decisions. Grasp of the total situation usually improves when viewed from various positions. (17:496)

2. Delay coupled with careful consideration is usually better than snap judgment. (17:497)

General Considerations

Direct Teacher Aid in Problem Solving

Research consistently has shown that direct teacher aid at various points in the problem-solving process improves student ability to reach solutions to immediate problems. The improvement varies directly with the amount of aid given. (10:412) The effectiveness of direct teacher aid upon lasting improvement of problem-solving abilities is subject to considerable question. It is one thing to aid a student to reach expediently an answer to a problem, and quite another to increase his problem-solving ability in a lasting, self-directing manner. When teacher aid or answers are given to a student who has not reflected upon their significance and who has no personal involvement in their development, they are not apt to have lasting effects. Aid of an indirect nature may serve as a means of bringing about significant general improvement of problem-solving ability. Development or principles relative to the giving of aid in a broad sense is the purpose of this study.

"Teachers," wrote Russell, "must avoid providing ready-made solutions to children's problems." (30:375) Limits to time and patience notwithstanding, it is reasonable for teachers to assume as a principle that they should avoid providing ready-made solutions.

Utilize the Questioning Technique

A carefully phrased and injected question is an excellent way for a teacher to give aid. Research studies have found this technique to be valuable in stimulating and focusing student attention on matters such as unnoticed conditions, data, or objectives. (30:356, 372-375) Such questions as "Can you defend that statement or do you wish to retract it?" and "Is this a hypothesis to be tested or a warranted conclusion?" were found to be useful in improving problem solving. (5:695-701) It can be stated as a principle that teachers, through carefully formed and properly timed questions, can help improve student problem-solving abilities by focusing students' attention on unnoticed conditions.

Transfer of Problem-Solving Abilities

Research dealing with the lasting effects of teacher instruction on student problem-solving abilities is probably the most important concern of this chapter. Much of the empirical research available has to do with the solving of immediate problems, but it gives little attention to lasting improvement of problem-solving abilities. Closely related to the long range effects of the improvement of problem-solving abilities is consideration of the transfer of these abilities to the variety of problems faced in life, now and in the future. There is a considerable body of research available on the transfer of learning as it relates to education in general. This research has application to problem solving because problem-solving method is recognized as one of the best avenues to learning.[1] Research directly concerned with the transfer of problem-solving abilities (that cited in the next several pages) showed no discrepancies

---

[1]Chapter III, p. 68.

when compared with the principles of transfer dealt with in a recent psychology of learning textbook. (18:364-377)

Consideration of the transfer of problem-solving abilities also demands attention to an individual's background of learning and retention, for transfer is dependent on them. To solve problems successfully, an individual must have a background of knowledge and skills that can be related to new problems, and attitudes favorable to successful problem solving. He must also have the ability to obtain further knowledge and to integrate the new with the old. (34:211)

What should be included in this background? Facts, skills, concepts, methods of solving problems, and attitudes. There should be a background of information available in any area in which problems are to be solved. (34:211) To solve problems in chemistry and in industrial arts, for example, the student needs some background of information in those areas. He also needs skill in gathering and organizing additional information. Representative skills are ability to locate information in a library, to skim reading materials, to read carefully and critically, to take notes, to write precis, and to outline.

Representative attitudes favorable to successful problem solving are willingness to suspend action or to withhold judgment until necessary data are gathered, thoroughness in exploration and fact finding, and appreciation of systematic organization of materials. A detailed development of the knowledge, attitudes, and skills needed as background for problem solving is in Chapter II.

Teachers Should Concentrate on Easily Transferable Background Learning

Regarding the background of knowledge, skills and attitudes that should be cultivated in a student, selection among the multitude of possibilities should be made on the basis of those that are the most easily transferable. Johnson wrote that improvement in handling "abstract verbal and numerical material will transfer to a wide variety of problems because many problems are either formulated in abstract terms or are solved by the aid of instrumental verbal and numerical patterns." (17:485) In contrast, he said improvement in handling facts and special relationships probably has less transfer value. (17:485)

The teacher should be responsible for selecting and emphasizing material which has the greatest possibility for transfer. (18:372) General information, generalizations and principles, methods of learning (solving problems), generalized attitudes, and methods of adjustment have wider variety of transfer than do specialized facts and attitudes, technical information, and knowledge acquired by rote procedures. Retention of general is usually superior to that of specialized and technical information. (18:358)

The teacher wishing to improve his students' problem-solving abilities should emphasize their building backgrounds of highly transferable experience comprising general information, generalized principles, methods of solving problems, and attitudes mentioned above.

Background Information Should Be Acquired by "Understanding" Methods

The usefulness and availability of knowledges and skills for application to problem situations depend sharply upon the manner in which they are acquired. (34:211) A teacher who concentrates upon student learning outcomes that have high transfer potential in solving problems does not insure their availability or usefulness when needed. Both Thorndike and Klausmeier emphasized that a student's original learning should be characterized by understanding and meaningfulness, that it should be generalized, organized, and applied in a variety of contexts. (34:211-212; 18:365)

Duncan summarized four studies that dealt with transfer following training by memorization versus training by various methods which emphasized understanding. Students who learned by understanding methods showed superior performance on transfer to complex problems, but showed little difference on transfer to simple tasks. (10:399)

It is interesting to note that a student's background of information, attitudes, and abilities, although acquired in an understanding or meaningful way, is not always available for transfer. (10:399, 405-406) What seems to be necessary is the student's recognition of something similar, whether it be specific facts, principles, or recognition of some total pattern. (18:353)

Encourage Discovery of Principles as Contrasted with Direct Telling

Separate studies by Forgus and Schwartz, and by Haselrud and Myers showed that groups of students that had to discover a principle before using it were superior in transfer to groups that were given the principle directly. (11:213-214; 15:293-298) Studies by Ray and by Rowlett showed that students in their test groups who learned through a directed discovery method were superior in both retention and transfer to those who were given principles directly. (27:459; 29:4589-4590)

Directed Discovery Is More Efficient Than Independent Discovery

Research just cited indicates that a teaching approach which focuses student attention on discovery of a principle needed for solving a problem is superior to approaches which furnish the principle directly. Research results are available that help to clarify the discovery approach. Corman cited a number of studies which indicated that giving some outside direction to aid in discovery is more effective than giving none. (8:461) Craig summarized the situation:

> The evidence indicates that teachers and experimenters should be liberal with information designed to assist learners in the discovery of principles. Large amounts of external direction now may help to insure that the learner will have an adequate background of knowledge to direct future discovery. (9:234)

Craig's study showed that directed discovery did not harm transfer in comparison with independent discovery. The important point seems to be that the element of discovery on the part of the individual must be retained if transfer potential is to remain high. Unfortunately, there appear to be no research results which can help the practicing teacher to determine what an optimum degree of direction is for aiding student discovery of principles without reduction of transfer potential.

Employ a Variety of Problems Using a Number of Approaches

Experimental research seems to indicate that students whose training embraces several approaches or methods for solving a number of kinds of problems are better able to transfer their problem-solving abilities to new and different problems than students whose training was concentrated on one kind of problem. (1:239-244; 2:15-18; 14:51-65) Students trained in solving one kind of problem were superior, however, in solving new problems of like nature. (2:15-18)

Johnson cited a study of transfer in which four groups of students were trained separately in four kinds of reasoning problems. Each group was trained in one kind only. Although each group improved in respect to the kind of problem in which it was trained, there was little transfer to the three kinds of problems of the other groups. (17:484) In view of the results of these studies it seems reasonable that teachers interested in the transfer of students' problem-solving abilities to future problems should emphasize the solving of a variety of problems and encourage the use of a number of approaches. Yet, if the kinds of problems that will arise in the student's future are known, experiences in solving them are likely to improve ability to solve these specific kinds of problems.

Begin with Easy Problems and Progressively Increase Their Difficulty

Johnson mentioned research results which demonstrated that when children begin on easy problems and progress to more difficult ones, they approach the new problems with confidence and persistence. (17:485) The point here is that confidence and persistence is more likely to develop when problems progress in complexity.

Encourage Insightful Behavior

Trial and error, insight and gradual analysis are descriptive of the range of behavior evoked by different types of problems at different levels of difficulty, according to Russell. They should be regarded as overlapping rather than mutually exclusive concepts. Trial and error behavior is seldom a completely blind or random approach, but more accurately is a process of trying different approaches that show some degree of promise of leading toward a goal. (30:268)

Russell observed that "there is some agreement that trial and error behavior is likely to occur in puzzle situations not understood by the organism, whereas insightful behavior may occur in situations which the subject can perceive in a meaningful way." (31:650)

It seems reasonable, in light of Russell's observations, to state the following principles. First, the teacher should realize the existence of an overlapping relationship of trial and error, gradual analysis, and insightful behavior, and should recognize the possible appropriateness of each in different kinds of problem situations. Second, the teacher, in recognizing that insightful problem solving is usually most desirable, whether it is sudden or gradual, should be careful to design or to encourage pursuance of problems that students can solve meaningfully. Student success in insightful problem solving probably will encourage the continuation of insightful behavior. Problems provoking students mainly to random trial-and-error attempts at solutions are likely to encourage the continuation of behavior that is not insightful.

Increased Concreteness of Problem Presentation May Aid in Problem Solving

Increasing the concreteness of the presentation of teacher-designed problems to a class, it is assumed, improves conditions for problem solving, particularly with children as compared to adults. Experimental research seems to have produced inconclusive results on this tenet. Lorge and others found no significant differences in the quality of solutions to problems presented at seven levels of abstraction ranging from written description, through photography and models, to actual, full-sized field settings. (22:160-166; 23:17-24) Because this study was done with adults it is risky to draw inferences regarding young children. Also, the lack of significant differences to be found in the study could be accounted for by the fact that all the subjects were allowed to ask questions freely about anything not clear to them. Further, since the problems were solved by teams as well as by individuals, interpretation of the results of the study may be clouded in terms of individual behavior.

Gundarson in her study which dealt with second grade children, indicated that extended experience with concreteness and semi-concreteness leads to improvement in problem solving. (13:435-461)

Russell pointed out research studies which indicated the appropriateness of concreteness in children's problem situations. (30:274-275) The ability to cope successfully with increasingly abstract problems increases with maturity.

Studies cited by Duncan showed both no difference and rather clear-cut differences favoring increased concreteness. (10:407-408) One study, the results of which showed differences favoring concreteness, was done with children and, therefore, tends to support the principle that increasing the concreteness of problems presented to children improves problem solving at that level of maturity. It may also be said, but with reservation, that increasing the concreteness of presentation may not be as important with adults. Because of individual differences and of wide variation in problems, it is not possible to name an age when problem solvers are able to handle the abstract. It is probable that students of the secondary school level vary almost the full range in their ability to handle abstract problems. Increased concreteness of problem presentation may aid in problem solving, particularly with younger persons.

Graphic Aids Should be Helpful

Russell referred to research studies which demonstrate conflicting results as to the usefulness of graphic aids, such as charts, diagrams, balance sheets, and check-lists, in the solution of problems. (30:371-372) The usefulness of presenting problems graphically as a technique in problem solving, Russell said, is probably dependent upon the nature and complexity of problems and the abilities of students or teachers to diagram accurately and ingeniously. At a later date, however, he wrote that graphical aids and other semi-concrete materials have demonstrated values in improving problem solving. (31:656)

Do Not Hold Student Problem-Solving Process to Models of Sequence

There is evidence of wide variation in the sequence of the thinking process in problem solving. After a study of more than 500 subjects working on various mathematical problems, Buswell and Kersh concluded that variety is a more striking characteristic than similarity in the sequence of the thinking process. They said the results of their study gave no evidence to support the notion that problem solving must follow precise models. (6:63-148) A study by Kropp indicated a similar conclusion. (19:385-388) Russell summarized research on the thinking process in problem solving as varying "with the nature of the task, with the methods of attack known to the solver, with the personal characteristics of the solver, and with the total situation in which the problem is presented." (30:270)

Russell clearly recognized variation in process, but he wrote that "problem solving may be generalized and verbalized with older children to provide them with a possible series of steps for solving problems and for checking the validity of conclusions." (30:376)

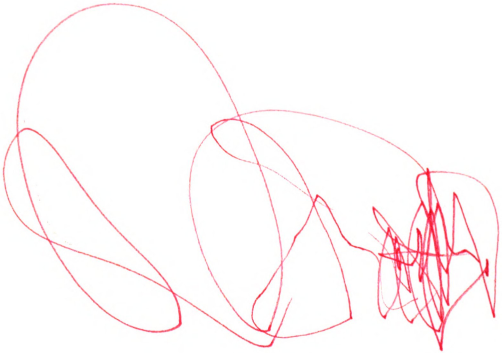
Russell's position may appear to be contrary to Dewey's on the subject of student consciousness of the steps of problem solving.[2] It is impossible, however, to discern from Russell's brief treatment the precise meaning of his position as compared with Dewey's. Dewey opposed the concept of teachers focusing their students' conscious attention on formal process preceding problem solution. He said he thought attempts to focus formal process should occur only when there is need to locate a difficulty causing an unusual perplexity, to identify previously successful methods, or to clinch a topic so knowledge of it will carry over and be an effective resource in further topics. Russell's discussion of process in problem solving is too cursory for the reader to attempt to prove or disprove any possible conflict between his ideas and those of Dewey in his expansive treatment of the subject. If Russell meant to communicate the idea that the problem-solving process can be formalized with more mature students, this may contribute a significant idea which can be added to Dewey's concept.

Required Writing of Steps Is of Questionable Worth

Hudgins reported that in his study, subjects who had

---

[2]Chapter IV, pp. pp. 129-131.



practice in writing down steps used in solving problems did not improve their problem-solving performance more than those who did not list steps. (16:40) The results of this study give some experimental evidence that requiring students to write out steps of procedure is a technique of doubtful value for improving problem-solving performance.

Problem Solving in Groups Appears to Have Potential

Group problem solving has been a subject of increasing interest for experimental researchers during the past decade. Although many studies have compared group with individual problem solving and have studied the dynamics of group problem solving, the results of the studies are highly tentative because of the variety of problem situations used and the number of other variables involved.

In general, it appears that group problem solving is a promising technique for teachers to use because it should bring about improvement of the individual's ability to solve problems and increase his skill as a participating group member. There seems to be especial implication here in the perpetuation and improvement of democratic process.

Johnson suggested that groups can be used to help solve individual problems. (17:498) Group action may serve to sharpen the individual's problem definition, solution production, and critical judgment. (30:270) Groups can aid in individual problem solution because the interaction of an individual with a group may cause a clarification of the individual's thinking and may stimulate production of a greater number and wider variety of tentative solutions than would be possible if he were working alone. (30:270)

Lorge, and others carefully pointed out that group procedures may also have disadvantages because "a single member, or coalition of members may retard the group by holding out for its kind of solution." (21:369)

There was no significant difference in the effect on general problem-solving ability, Hudgins reported as a result of his study, whether individuals worked alone or in small groups. (16:40) This evidence serves to soften the temper of any generalization that group problem solving is a superior technique for improving problem-solving abilities.

A few studies gave clues to techniques and conditions that a teacher might attempt to establish in group problem-solving situations. But solid, convincing evidence upon which to base actions was lacking.

Maier and Maier found that developmental discussion (leader directed) leads to a higher quality of group decision making than free discussion (not leader directed). (24:323) It was their opinion, however that

> The above findings apply only to a problem in which emotional involvement is not an important aspect of the problem. It is believed that with other types of problems the "free" type of discussion may be more effective than the "developmental." (24:323)

Teachers should note that, so far as experimental research can determine, the encouragement of cooperation rather than competition between members of a group is an unsettled question. Phillips cited conflicting evidence after reviewing eight studies, the results of which were equally divided between cooperation and competition. Phillips' experimental study found that groups were more efficient in competitive situations than in cooperative ones. (25: 127-132)

Help Problem Solvers Find Causes of Their Errors

A general suggestion by Johnson to teachers interested in improving student thinking ability is that their efforts should be based on a reasonably good analysis of student thinking. Then if a teacher can diagnose reasons for poor thinking, he can attempt to improve it. (17:482)

Problem solvers often need aid in locating the specific sources of their errors. (30:376) The individual may find that his difficulties lie in the basic communication skills of reading and listening, in arithmetical processes, in locating data, in attitudes (such as thoroughness), in rigidity, in reasoning through to consequences, or in any of a number of other areas. Becoming aware of the source of his difficulty is an individual's first step toward its correction.

Johnson suggested attention to a few possible techniques teachers might use to locate students' difficulties.

1. The nature of the final result, especially if there are errors in the solution, may permit inferences about the locus of errors.
2. If the functions can be examined separately, direct observation of the defective functions may be possible.
3. The source of an error may be located <u>ex post facto</u> by correcting it. If the conditions of preparation are improved, for example, and the final result improves, there must have been something wrong with the preparation. (17:483)

Johnson then indicated that specifically identified difficulties may be at least partially relieved by practice or exercise at the point of trouble. (17:488) He suggested that teachers may be able to improve student problem definition by using a technique of allowing groups of students independently to formulate problem definitions and then to compare their results. Another technique he suggested for use by teachers interested in improving student problem definition is provision for frequent brief intervals of time during which students could produce, free from criticism and judgment of their worth, numerous imaginative suggested solutions--a procedure much like "brainstorming." (17:489, 493)

The idea of teachers providing exercise for students in areas of their difficulty, as suggested by Johnson, may seem to be in opposition to Dewey's belief that the value of exercises is diminished if they are carried on out of context with purposes which give them meaning and direction.[3]

---

[3] Chapter IV, pp. pp. 102-103, 112.

It seems clear, however, that Johnson might ask that the same condition exist, because he subordinated exercise or practice, as a means of relieving difficulty, to diagnosis of the difficulty. He thus placed exercise in context with purpose. It should be understood that students, as well as the teacher, must be aware of their purposes.

In summarizing his research, Russell wrote, that "if there is a single key to the improvement of problem-solving abilities it seems to lie in instruction for a varied attack on problems." (30:374) He emphasized that results of all the experimental research studies he included in his study demonstrates that an active attack pays off. (30:374)

Summary

In summary, the findings of experimental research dealt with in this chapter seem to warrant the following principles for improving problem-solving abilities.

I. Preparation

A. The problem should be the problem solver's. It should be closely related to his experience and interests, and it should be important to him.

B. Develop student awareness of problems by providing a rich and varied experiential background of question- and curiosity-provoking situations. Such a background can be enhanced by a teacher attitude that is favorable to student questioning, and by an environment that exceeds the limits of the traditional classroom and encompasses the world outside.

C. Develop an optimum level of anxiety and emotional involvement for each individual. The level should be neither devoid of nor loaded with anxiety, and it should be sufficiently balanced to induce adequate motivation.

D. Develop meanings involved in problems by directed discussion of them and by encouraging direct student experience with them. Student experience can be provided in field trips or in direct handling of material objects.

E. Encourage careful delimitation of what is included in and what is excluded from problems.

F. Reduce problems to singular goals, because problem-solving efficiency varies inversely with the number of goals.

G. Encourage the modification and redefinition of goals, because experience brings new factors into play which can change the complexion of problems.

II. Production

A. Encourage in students the ability to shift set to make possible occurrences of alternative solutions.

B. Allow time for student suggestions to occur, and support the temporary abandonment of the problem as technique for promoting suggestion occurrence.

C. Encourage students to explore all the possibilities of an approach before abandoning it for another.

D. Promote student use of the calculated guess made on the basis of some facts. That guess can be used by a student as a tool for testing evidence and precipitating suggestions.

III. Verification

A. Encourage students to develop and verify hypotheses through reasoning before acting upon them.

B. Promote student testing of tentative hypotheses experimentally or by action.

C. Encourage students to shift their points of view before reaching final decisions.

D. Promote an attitude among students that delay, coupled with careful consideration, is usually better than snap judgment.

IV. General Considerations

A. Direct teacher aid at various points in the problem-solving process improves student ability to reach immediate solutions; but the effectiveness of this practice on lasting improvement of student problem-solving abilities can be seriously questioned. Teachers generally, therefore, should avoid providing students with ready-made solutions.

B. Carefully formed and inserted questions by the teacher can stimulate student thinking about unnoticed factors.

C. Success in solving new problems demands (1) that students have a background of knowledge and skills that they can relate to new problems, (2) that students have sufficient ability to obtain further information and to integrate the new with the old, and (3) that they have attitudes favorable to successful problem solving.

D. Teacher concentration should be on easily transferable background learning--including general information, generalizations and principles, methods of learning (solving problems), generalized attitudes and methods of adjustment--rather than on specialized facts, technical information, and knowledge acquired by rote procedure.

E. Students should acquire background information in diverse ways, characterized by understanding and meaningfulness, so that it will be available and useful when needed.

F. Teacher-guided discovery of principles seems to be more promising than direct telling or independent discovery.

G. A variety of problems using a number of approaches should be emphasized by the teacher to increase student ability to cope with a wide range of problems.

H. If the kinds of problems that will arise in the student's future are known, experiences in solving them are likely to improve ability to solve these specific kinds of problems.

I. Beginning with easy problems and progressively increasing their difficulty seems to increase the confidence and persistence of the problem solver.

J. The overlapping relationship of trial and error, gradual analysis, and sudden insight in solving problems, as well as the possible appropriateness of each in different kinds of problem situations should be understood by teachers.

K. Recognizing insightful problem solving, whether it be sudden or gradual, as usually being most desirable, the teacher should be careful to design or encourage pursuance of problems which are possible for students to solve in an insightful way.

L. Increased concreteness of problem presentation may aid students in problem solving, particularly younger persons.

M. Graphic aids have value in improving problem solving.

N. Do not hold student problem-solving process to models of sequence.

O. Problem-solving process may be generalized and verbalized with older children to provide them with a possible series of steps for solving problems and for checking the validity of conclusions.

P. The practice of requiring students to write out steps of procedure is a technique of doubtful value for improving problem-solving performance.

Q. Group problem solving may be a promising technique because interaction of an individual with a group may cause clarification of individual thinking and stimulate a greater number and wider variety of tentative solutions than would be possible if an individual were working alone.

R. Teachers can help problem solvers to find the causes of their errors and to correct them by diagnosing the reasons for poor student thinking and by giving students practice in the areas of difficulty.

Bibliography

1. Ackerman, W., and Levin, Harry. "Effects of Training in Alternative Solutions on Problem Solving," Journal of Educational Psychology, XLIX (October, 1958).

2. Adams, J. A. "Multiple vs. Single Problem Training in Humans," Journal of Experimental Psychology, XLVIII (July, 1954).

3. Adamson, R. E., and Taylor, D. W. "Functional Fixedness as Related to Elapsed Time and to Set," Journal of Experimental Psychology, XLVII (February, 1954).

4. Anderson, Scarvia B. "Problem Solving in Multiple-Goal Situations." Unpublished Ph. D. dissertation, Department of Psychology, University of Maryland, 1955, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XVI (1956).

5. Blair, G. M., and Goodson, M. R. "Development of Scientific Thinking Through General Science," School Review, XLVII (November, 1939).

6. Buswell, Guy T., and Kersh, B. Y. "Patterns of Thinking in Solving Problems," University of California Publications in Education, XII (April, 1956).

7. Carpenter, Finley. "Educational Significance of Studies in the Relation Between Rigidity and Problem Solving," Science Education, XL (October, 1956).

8. Corman, Bernard S. "Problem Solving and Related Topics," Review of Educational Research, XXVIII (December, 1958).

9. Craig, R. C. "Directed vs. Independent Discovery of Established Relations," Journal of Educational Psychology, XLVII (April, 1956).

10. Duncan, Carl P. "Recent Research on Human Problem Solving," Psychological Bulletin, LVI (November, 1959).

11. Forgus, R. H., and Schwartz, R. J. "Efficient Retention and Transfer as Affected by Learning Method," Journal of General Psychology, LVI (April, 1957).

12. Fox, David J. "The Effect of Increasing the Available Time for Problem Solving on the Relative Quality of Decisions Written by Individuals and Groups." Unpublished Ph. D. dissertation, Department of Psychology, Columbia University, 1955, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XV (1955).

13. Gundarson, Agnes G. "Patterns of Young Children in Learning Multiplication and Division," Elementary School Journal, LV (April, 1955).

14. Harlow, H. F. "The Formation of Learning Sets," Psychological Review, LVI (January, 1949).

15. Haselrud, G. M., and Myers, S. "The Transfer Value of Given and Individually Derived Principles," Journal of Educational Psychology, XLIX (December, 1958).

16. Hudgins, Bryce B. "Problem Solving and Group Experience," Journal of Educational Psychology, LI (February, 1960).

17. Johnson, Donald M. The Psychology of Thought and Judgment. New York: Harper & Brothers, 1955.

18. Klausmeier, Herbert J. Learning and Human Abilities: Educational Psychology. New York: Harper & Brothers, 1961.

19. Kropp, R. P. "Relation Between Process and Correct Item Response," Journal of Educational Research, XLIX (January, 1956).

20. Lee, Doris M., and Bingham, Alma. "Intellectual Processes," Review of Educational Research, XXIX (April, 1959).

21. Lorge, Irving, and Others. "A Survey of Studies Contrasting the Quality of Group Performance and Individual Performance," Psychological Bulletin, LV (November, 1958).

22. ________, and Others. "Problem Solving by Teams and By Individuals in a Field Setting," Journal of Educational Psychology, XLVI (March, 1955).

23. ________, and Others. "Solutions by Teams and By Individuals to a Field Problem at Different Levels of Reality," Journal of Educational Psychology, XLVI (January, 1955).

24. Maier, N. F., and Maier, R. A. "An Experimental Test of the Effects of 'Developmental' vs. 'Free' Discussion of the Quality of Group Decisions," Journal of Applied Psychology, XLI (October, 1957).

25. Phillips, Beeman N. "Effect of Cohesion and Intelligence in the Problem Solving Efficiency of Small Face to Face Groups in Cooperative and Competitive Situations," Journal of Educational Research, L (October, 1956).

26. Ray, Wilbert S. "Verbal Compared With Manipulative Solutions of an Apparatus Problem," American Journal of Psychology, LXX (June, 1957).

27. Ray, Willis E. "An Experimental Comparison of Direct and Detailed Discovery Methods of Teaching Micrometer Principles and Skills." Unpublished Ed. D. dissertation, Department of Industrial Education, University of Illinois, 1957, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XVII (1957).

28. Rokeach, Milton. "The Effect of Perception Time Upon Rigidity and Concreteness of Thinking," Journal of Experimental Psychology, XL (April, 1950).

29. Rowlett, John D. "An Experimental Comparison of Direct-Detailed and Directed Discovery Methods of Teaching Orthographic Projection Principles and Skills." Unpublished Ed. D. dissertation, Department of Industrial Education, University of Illinois, 1960, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XX (1960).

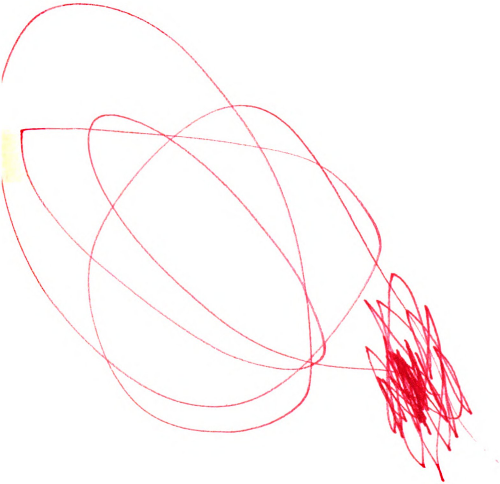
30. Russell, David H. Children's Thinking. Boston: Ginn, 1956.

31. ________. "Higher Mental Processes," Encyclopedia of Educational Research, a Project of the American Educational Research Association. 3d. ed. Edited by Chester W. Harris with the Assistance of Marie R. Liba. New York: Macmillan Co., 1960.

32. Sinha, D., and Singh, T. R. "Manifest Anxiety and Performance on Problem Solving Tasks," Journal of Consulting Psychology, XIII (October, 1959).

33. Spencer, R. E. "The Relation Between Personality Anxiety and Selected Problem Solving Processes." Unpublished Ph. D. dissertation, College of Education, University of Illinois, 1957, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XVII (1957).

34. Thorndike, Robert L. "How Children Learn the Principles and Techniques of Problem Solving," Learning and Instruction. Forty-ninth Yearbook of the National Society for the Study of Education, Part I. Chicago: University of Chicago Press, 1950.



CHAPTER VI

PRINCIPLES FOR DESIGNING AND CONDUCTING LEARNING EXPERIENCES FOR IMPROVING PROBLEM-SOLVING ABILITIES

Need for Guiding Principles

The teacher who accepts improvement of student problem-solving ability as an important educational goal is faced with the task of designing and conducting learning experiences which will serve as means for its achievement. Teachers and teacher educators alike have need for guiding principles developed through careful study and synthesis of available knowledge pertinent to designing and conducting learning experiences that improve student problem-solving abilities. In this chapter, such guiding principles are set forth. They were developed by examination of problem solving as an objective and a method of learning; and as the result of research in selected works of educational philosophers, Dewey and Kilpatrick, and in selected experimental research projects. The comprehensive set of principles presented are grouped under the five phases of problem-solving plus an additional category, General Considerations. They represent the merging of the concepts of the philosophers with the findings of the experimental researches.

Principles Defined and Described

Before the principles in this chapter are presented, a brief examination of the nature and role of principles in teaching may be helpful. Often, a variety of interpretations becomes attached to a term, as is the case with the word "principle" used by educators.

The framers of the Cardinal Principles of Secondary Education apparently used "principle" synonymously with primary objectives of education like health, command of fundamental processes, and worthy home membership. (2:188) "Principle" also may refer to certain course content such as the laws of genetics in biology, generalizations regarding relationships in art, or practices necessary for safe operation of power equipment in industrial arts. Frequently, "principles" are regarded as policy statements useful as standards by which to judge individual cases. For example, in our society, it is considered wrong to steal; parents are expected to provide for the needs of their children. Hence, the word "principle" is used as a measuring stick for judging ethical values.

In this study, principles should be regarded as functional guides to teachers interested in directing students toward achieving goals. They should serve to keep instructional activities headed in the right direction. Some professional agreement on the meaning of teaching principles is indicated by the following definition in the Dictionary of Education.

> Principle, teaching: a concept or generalization that serves as a guide to teachers in directing learners toward the attainment of educational goals and objectives. (1:412)

A representative principle that will be discussed later in this ~~chapter~~ paper is:

> Teachers should not attempt to focus the student's attention on formal process at the beginning of a problem-solving situation. Conscious attention to formal process should be called upon to locate some unusual perplexity or some difficulty causing an error.[1]

That principle should serve to guide teachers in planning and conducting student learning experiences, to indicate to them that they should avoid dwelling on formal procedure as an initial activity in aiding the student to solve problems, and to help them turn student attention to examination of process when difficulty is encountered.

Risk wrote that principles are "statements of generalization or truth that constitute a guide for the selection and use of learning steps, teaching steps, devices, techniques, etc." (2:16) This statement is significant because it indicates that principles are not in themselves, methods, devices, and techniques, but are guides for the selection and use of methods, devices, and techniques. For the purpose of this study (paper), principles should be regarded

---

[1]This Chapter, p. 209.

as statements of generalization or truth that can guide the teacher in selection and use of methods, devices, and techniques which will direct students toward improvement of their problem-solving abilities, and achievement of other educational goals. Some principles focus on teaching method or procedure, and others are concerned with technique.

The principles here developed vary in their degree of specificity or directness to their application in actual teaching situations. Some represent broad, general concepts; others are quite specific. Illustrative of the former is a principle that will be considered later in this chapter: "The improvement of student problem-solving abilities is best accomplished indirectly by the teacher's regulating the conditions which guide it."[2] Representative of the latter is another principle to be found later in the chapter: "Definition of complex problems is aided by experimentation."[3]

Principles herein, as defined above, should be distinguished from objectives of instruction. Principles guide the efforts of the teacher in directing his students toward achievement of ends. Principles are not objectives or ends, but are the concepts and generalizations a teacher can use

---

[2]This Chapter, p. 191.

[3]This Chapter, p. 201.

to direct means for achieving objectives. Principles serve indirectly as means for achieving ends by virtue of the fact that they directly guide the teacher in the selection and development of means. For instance, a principle which suggests to the teacher that he make available equipment and materials to his students so they may verify experimentally their reasoned hypotheses, guides the teacher toward providing his students experience with such materials as means for their achieving improved problem-solving abilities.

Using the Principles Developed in This Study

The principles listed in the last pages of this chapter should be used to guide the teacher in designing and conducting functional learning experiences that can improve his students' problem-solving abilities. The principles are not learning experiences, a course of study, or a curriculum. They are guides for the planning of experiences, courses of study, and curricula.

This study did not attempt to appraise the various organizational patterns of secondary school curricula for their potential for improving student problem-solving abilities. The potential rests with the individual teacher and the way he works with his students. Within a wide variety of organizational patterns, the individual teacher can do much to improve student problem-solving abilities. The principles in this chapter are offered to help guide him.

These principles should be regarded as tentative rather than final, as limited in comprehensiveness rather than complete. Their validity is dependent upon a number of factors, including the scope of this study; the reliability and accuracy of the sources drawn upon; and the ability of the researcher to recognize, interpret, develop, and report them. Readers, because of personal differences in perceptions and experiential backgrounds, may vary in their interpretations of the meanings of the principles.

The principles should not be interpreted narrowly, as restricted to the phase of problem solving under which they will be assembled. Most have broad relevance. For example, a principle listed later in the chapter relative to student procurement of data through observation, experimentation, reference to authoritative written or spoken information, and memory or past experience, appears under the phase, Suggestion Occurrence.[4] Yet it is obviously relevant to the other phases.

The principles in this chapter also should not be interpreted without reference to their identification and development earlier in this study--and in some cases, not without reference to the sources from which they were derived.

---

[4]This Chapter, pp. 201-202.

Since they were drawn from general sources which favor no one school subject, principles in this study should be of value for use by teachers of other subjects. The principles are chiefly directed to teachers at the secondary school level. But because most of the sources considered were not confined to secondary school level, the principles also should have value to teachers at elementary school and college levels.

As stated in Chapter I, "the primary purpose of this study is to develop principles for guiding industrial arts teachers when designing and conducting learning experiences which will improve student problem-solving abilities."[5] The principles presented in this chapter accomplish this purpose in a general respect. Their implications as applied to the teaching of industrial arts, however, will be examined and illustrated in the chapter to follow.

Principles Underlying the Improvement of Problem-Solving Abilities

In the first three chapters of this study, several concepts were developed and sustained by rational and authoritative means. They provide a basis for the identification of more specific principles derived from the works of Dewey and Kilpatrick, and from experimental research

---

[5]Chapter I, p. 1.

projects. They are summarized here as underlying principles which should give orientation to the main body of principles which follow.

1. The greatest gains in improving student problem-solving abilities can be effected when the teacher consciously plans learning experiences with the goal of improving problem-solving ability in mind. This concept is contrasted with a rejected view that equal gains can result, incidentally, from student pursuance of other goals. An initial planning activity of the teacher is to analyze and define, in terms of expected behavioral outcomes, student problem-solving abilities which need improvement. Student problem-solving abilities serve as specific sub-objectives for which the teacher can plan instructional activities. The planner should be cognizant of the extremely close relationship between ends and means.

2. The improvement of student problem-solving abilities is best accomplished indirectly by the teacher's regulating the conditions which guide it, and providing a favorable climate for it. (Although this principle was developed in Chapter IV, it is included here because of its major significance.)

3. Exposing students to direct experience in grappling with and attempting to solve real-life problems through the use of scientific or problem-solving method is the teacher's most appropriate and promising way to achieve improvement

in problem-solving abilities. Other teaching methods can and do make contributions, but direct experience appears to be the most promising.

4. Problem solving is both a method and an objective. It is a means and a method of achieving numerous educational objectives, including improvement of problem-solving abilities. It is also an end and an objective of education because of its significance as a method in living and learning.

5. Problem-solving method is practically synonymous with learning, and there are indications that problem solving is generally equal or superior to other methods of learning.

6. Learning experiences, to be educative, should provide for further growth, for interaction between individual and environment, and for intelligent managing of ends and means. They should be continuous with past and future experience, should have both active and passive elements, and should include reflective thinking.

7. In designing and selecting problem situations suitable for improving student problem-solving abilities, it is important that the teacher make the distinction between genuine problems and those which are not. The following criteria serve to define true problem situations.

a. There should be an objective in view.

b. There should be something blocking the objective.

c. There should be awareness or consciousness of the goal and blocking obstacle. There should be intellectual activity.

d. There should be a high degree of subjective identification or motivation.

e. Problem situations at both ends of a problem difficulty continuum, which range from the extremes of the completely familiar (rectifiable through unthinking, habitual response) to puzzles (solvable through accident, rational means being of little consequence), are less desirable problem situations than those in between and should be minimized.

Principles for Designing and Conducting Learning Experiences for Improving Problem-Solving Abilities

The principles which follow constitute the main body of findings of this study.

I. Source and Nature of Problems

A. Develop student awareness of problems by providing a rich and varied experiential background of question- and curiosity-provoking situations. Such a background can be enhanced by a teacher attitude that is favorable to student questioning and by an environment that exceeds the limits of the traditional classroom and encompasses the world outside.

B. Identify or develop problems that emerge from actual situations in student experience. These may come from the students' background of general experience or from experiences provided by the teacher.

C. Problems should be vital and real in the life of the student and should include a felt difficulty.

D. It is desirable that both students and teachers be fully involved in the identification and selection of problems. Problems selected should be the students'. It is the responsibility of the teacher to guide in selection of problems.

E. Develop an optimum level of anxiety and emotional involvement for each individual. The level should be neither devoid of nor loaded with anxiety, and it should be sufficiently balanced to induce adequate motivation.

F. Problems should include a balancing of the old and the new. Without the new or strange elements there would be no problem; without the old or familiar, inquiry might be hopeless.

G. Problems should provide for a balancing interaction of concrete and abstract thinking.

H. School activities can furnish real potential for development of problem-solving abilities because they provide for the emergence of numerous real problem situations which require ordering of thought through action and management of means-consequence relationships. Activities in themselves may not be intellectual. They can provide the conditions from which necessity for intelligence and reasoning emerge.

I. Activities or problems should have high potential for forming habits of observation and inference.

J. Externally assigned or dictated activities and problems should be approached with caution because they may be low in personal commitment and intrinsic satisfaction.

K. To guide the course of action, activities and problems should have ends that are known and attainable.

L. Abundant opportunity for active use of materials and equipment should be provided for.

M. Activities and problems to be avoided are those which follow definite prescription and dictation, or which reproduce, without modification, ready-made models. Such problems do not require intelligent perception and elaboration of ends.

N. Maximum gain should be realized when the content of activities, whether it be physical or intellectual, has been subjected to a minimum of pre-perfection by the teacher.

O. Activities and problems should be concerned with wholes. They should place skills, attitudes, and knowledge in immediate context with over-all purposes.

II. Problem Definition

A. Help students to search for the causal conditions of a problem situation.

B. Encourage careful delimitation of what is included in and what is excluded from the problem.

C. Reduce problems to singular goals, because problem-solving efficiency varies inversely with the number of goals.

D. Impulsive, direct action should be balanced or delayed by reflective thinking so that the problem can be reasonably well defined.

E. Develop meanings involved in problems by directed discussion of them and by encouraging direct student experience with them. Student experience can be provided in field trips or in direct handling of material objects.

F. Definition of complex problems is aided by experimentation.

G. Insistence that students write down the conditions of definition may be desirable in some complex situations, but can be distinctly deadening and undesirable in others.

H. The quality of the definition sets the stage for the remainder of the inquiry; hence, thoroughness should be encouraged.

III. <u>Suggestion Occurrence</u>

A. Since suggestions seems to occur with the interaction of (1) developing an acquaintanceship with existing conditions in a situation and (2) past experience, the teacher should direct his efforts toward providing experiences which help create a rich experiential background, and toward encouraging the problem solver to saturate himself with information surrounding the problem situation.

B. Encourage student examination of the problem situation for relatively fixed factual conditions.

C. Experience in the procurement of data should be encouraged through a number of channels, including observation, experimentation, reference to authoritative written or spoken information and memory or past experience.

1. Development of student observation abilities is not promoted effectively through teacher-designed exercises carried on out of the context of their application to over-all purposes.

2. Provision should be made for conditions in which observation is an active process of exploration, has an element of suspense, and is scientific in nature.

3. Reference to authoritative written or spoken information, which is relevant to the problem at hand, should be encouraged.

4. Need is apparent for instructional materials in the form of reference books, apparatus, tools, and physical materials to be used in data collection.

D. Encourage in students the ability to shift set to make possible occurrences of alternative solutions.

E. Encourage the problem solver to alternate between a broad, general absorbing of information and a sharp, localized concentration on a few pertinent facts.

F. Time should be provided for incubation through breaks or diversions from concentrated attention on problems.

G. Encourage students to explore all the possibilities of an approach before abandoning it for another.

H. Promote student use of the calculated guess made on the basis of <u>some</u> facts. That guess can be used by a student as a tool for testing evidence and precipitating suggestions.

I. Problem redefinition may serve to start the flow of a new group of suggestions.

IV. <u>Development of Hypotheses by Reasoning</u>

A. Encourage students to develop and verify hypotheses through reasoning before acting upon them.

B. Develop hypotheses from suggestions by encouraging alternation between gathering data and formation of ideas.

C. Promote an attitude of tentativeness in hypothesis development.

D. Encourage shift of context or point of view before reaching final decisions.

E. Encourage students to use promising ideas as guides in hypothesis development by searching the problematic situation for evidence that will support or reject them.

F. Promote ability to think through the implications or consequences of suggestions, ideas, and hypotheses by providing the kind of experiences that develop awareness of interrelationships--a background of meanings and concepts which are interrelated, not isolated and disjointed.

G. Promote an attitude among students that delay, coupled with careful consideration, is usually better than snap judgment.

H. Encourage students to explore the implications of each idea somewhat separately, leaving until later exploration of relationships to other ideas.

I. Ask students to defend their hypotheses.

V. Testing of Hypotheses by Experimentation

A. Whenever possible, encourage testing of reasonably verified hypotheses through experimentation.

B. Some hypotheses are only reasonably or logically verifiable because they are quite difficult or impossible to test experimentally. Others need not be experimentally tested, because increasingly comprehensive experiential background and maturity in reflective thinking provide the individual with ability to verify hypotheses with sufficient surety through use of reason.

C. Acquaint students with the procedures and practices of experimental testing which the culture has developed.

D. Provide students with equipment and facilities for testing hypotheses experimentally.

E. Failure of promising hypotheses to pass reasoned or experimental verification may be educative in terms of improving problem-solving abilities.

F. Encourage students to apply their reasonably and experimentally tested hypotheses in connection with or in prediction of future events.

G. Require students to undertake periodic appraisal so that new bearings may be taken, product can be inventoried, techniques or process generalized, relationships realized, and new problems identified.

VI. <u>General Considerations</u>

A. Practice or exercise carried on as an end in itself is unsound. It should be closely connected with a purpose, as means to achieving an end, and this should be visible to the student.

B. Direct teacher aid at various points in the problem-solving process improves student ability to reach immediate solutions; but the effectiveness of this practice on lasting improvement of student problem-solving abilities can be seriously questioned. Teachers generally, therefore, should avoid providing ready-made solutions.

C. The student should take his own steps in problem solving; the teacher should not take them for him.

D. Maintain a balance between furnishing too much and too little information.

E. Questioning as a valuable technique in stimulating thinking should include the following:

1. Questions should motivate the student to use material already learned in dealing with new problems.

2. Questions should direct the student to subject matter rather than to the teacher's aim, thus avoiding a "guessing bee" as to what the teacher is really after.

3. Questions should build for the student a large, inclusive situation within which there can be movement from one point to another, and within which meaningful relationships can be seen.

4. Questions should periodically require a survey and review of subject matter that has been covered to

extract its new meaning, and to gather together and hold what is significant.

F. Success in solving new problems demands (1) that students have a background of knowledge and skills that they can relate to new problems, (2) that students have sufficient ability to obtain further information and to integrate the new with the old, and (3) that they have attitudes favorable to successful problem solving.

G. Teacher concentration should be on easily transferable background learnings--including general information, generalizations and principles, methods of learning (solving problems), generalized attitudes and methods of adjustment--rather than on specialized facts, technical information, and knowledge acquired by rote procedures.

H. Students should acquire background information in diverse ways, characterized by understanding and meaningfulness, so that it will be available and useful when needed.

I. Teacher-guided discovery of principles seems to be more promising than direct telling or independent discovery.

J. A variety of problems using a number of approaches should be emphasized by the teacher to increase student ability to cope with a wide range of problems.

K. If the kind of problems that will arise in the student's future are known, experience in solving them is likely to improve his ability to solve these specific kinds of problems.

L. The overlapping relationship of trial and error, gradual analysis, and sudden insight in solving problems as well as the possible appropriateness of each in different kinds of problem situations should be understood by teachers.

N. Trial and error methods can be useful in problem solving if they are intelligently directed and if they lead to insightful understanding of cause and effect relationships.

N. Recognizing insightful problem solving, whether it be sudden or gradual, as usually being most desirable, the teacher should be careful to design or encourage pursuance of problems which are possible for students to solve in an insightful way.

O. Do not require or expect student thinking to follow rigidly models of problem-solving process. Some phases may be telescoped, some passed over lightly, and others may be expanded.

P. Teachers should not attempt to focus the student's attention on formal process at the beginning of a problem-solving situation. Conscious attention to formal process should be called upon to locate some unusual perplexity or some difficulty causing an error. Also, the student can be helped to identify previously successful methods, and to clinch topics for effective future use by giving his conscious attention to formal process.

Q. Problem-solving process may be generalized and verbalized with older children to provide them with a possible series of steps for solving problems and for checking the validity of conclusions.

R. The practice of requiring students to write out steps of procedures is a technique of doubtful value for improving problem-solving performance.

S. Beginning with easy problems and progressively increasing their difficulty seems to increase the confidence and persistence of the problem solver.

T. Increased concreteness of problem presentation may aid students in problem solving, particularly younger persons.

U. Graphic aids have value in improving problem solving.

V. Problem solvers should not be pressured by artificial time limits.

W. Group problem solving may be a promising technique because interaction of an individual with a group may cause clarification of individual thinking and stimulate a greater number and wider variety of tentative solutions than would be possible if an individual were working alone.

X. Teachers can help problem solvers to find the causes of their errors and to correct them by diagnosing the reasons for poor student thinking and by giving students practice in the areas of difficulty.

Bibliography

1. Good, Carter V. (ed.) Dictionary of Education. New York: McGraw-Hill Book Co., 1959.

2. Risk, Thomas M. Principles and Practices of Teaching in Secondary Schools. New York: American Book Co., 1947.

CHAPTER VII

APPLICATION OF PRINCIPLES TO INDUSTRIAL ARTS TEACHING

In this chapter, the principles discussed previously are applied specifically, through description of illustrative or sample learning experiences, to the designing and conducting of learning experiences in industrial arts. The samples incorporate almost all the principles, but do not necessarily include direct reference to each. Fundamental to the illustrations are the seven underlying principles summarized in the last chapter.[1] A number of learning experiences will be included to suggest to industrial arts teachers that they can employ a wide variety of problems using a number of approaches, and thus can reach many students and promote versatility in problem solving.

Problem in Selection of a Plan

Youngsters of junior high school age are generally gregarious and they usually enjoy playing games with their peers. In winter months they often gather informally at each other's homes to play indoor games, some of which involve vigorous muscular activity. Many youngsters would

---

[1]Chapter VI, pp. 194-197.

like to have the facilities available for a number of games --darts, box hockey, table tennis, shuffle board. A felt need for such facilities seems to emerge from children's experiences. Desire for one or more indoor games, felt difficulty, and a degree of anxiety or emotional involvement could easily represent a vital and real problem in the life of a child. A teacher-led discussion of games students like to play, and of their value in entertaining friends may sharpen student interest. Availability of a few games and illustrations of others in the industrial arts classroom may focus student attention on them. Opportunity to examine and play the games may develop in some students on optimum level of anxiety about owning similar ones. In such a situation, the teacher and students together can discuss the desirability of owning and building game equipment, thereby setting a problem situation.

Discussion can lead to compiling a list of games in which there is high student interest. The list may include box hockey, shuffle board, and others. Individuals then can choose the games that are of greatest interest to them, and groups can be formed to discuss each game. The benefits which accrue from exchange within a group can thus be provided.

The remainder of this illustration is limited to the problem of selecting or developing suitable plans for building the games. It represents a problem within an over-all problem of procuring suitable game equipment. Each group can focus attention on determining the qualities of good equipment for the game of its choice. The exchange of information in the groups can promote critical selection of plans and discourage groups from plunging uncritically into construction, using the first set of plans they happen to find. Discussion of box hockey equipment should lead to identification of several criteria such as desirable size, height of box from the floor, strength of parts, and free movement of paddles.

The groups should be encouraged to look at existing equipment, illustrations, and working drawings, and to study them to determine their desirable features. Many features of box hockey equipment can be identified by students as a result of their previous experience with the game. The teacher, however, can supply the basis in experience for recognizing good features by giving students opportunity to examine and tryout a game of box hockey. Thus, definition of the problem can be aided by experimentation.

The level of maturity of the class should affect the teacher's decision regarding the amount of direction he should give to group activities concerned with the determination of standards for a box hockey game. The teacher's presence and leadership may be needed in the discussions of immature groups, at the seventh grade level, for example. Groups having more maturity may require little teacher participation. Teacher expectations regarding thoroughness in defining problems also should be adjusted according to the level of class maturity.

With knowledge about several of the features of box hockey equipment resulting from investigation, experimentation and discussion, groups may select plans that seem to suit their criteria. Thus, their selections should be critical rather than impulsive. Perhaps as a compromise, some features of several plans may be combined. Decisions should be made largely on the basis of the groups' reasoning through the implications of alternative plans under consideration.

At this point, students should decide whether common group plans are to be agreed upon, or whether some students prefer to select their own plans. If the latter is the case, individual students may be asked to defend their decisions to the members of their groups. In either case, certain features of selected plans may appear to be unsatisfactory in the judgment of some individuals; so provisions should be made for discovering and investigating alternatives. The teacher can help by giving encouragement; removing time limits; answering questions; and providing reference resources, sketching materials, and tools for experimenting with structures and making models.

Problem in Social Living

When a class of students share the use of facilities of the industrial arts laboratory, problem situations quite naturally arise. Bottlenecks occur in the use of equipment, cutting tools are found in dull condition when they are needed, equipment may be left covered with debris, and tools may not be returned to their proper places. Assume that a class spontaneously has been caring for laboratory clean-up. The class period ends one day before members of the class have attended to their clean-up responsibilities. The teacher should immediately call the situation to the attention of the class, and thereby set a problem situation. The next time the class meets the problem should be called to the students' attention for solution by the group. It should be made clear that leaving an untidy laboratory at the end of a class period is a concern of teacher and students alike. Students' attention should be focused on the consequences of leaving the classroom in disarray. The teacher could ask how they should feel if they were to enter the room that had been left in cluttered condition by the previous class. This kind of problem seems to provide the possibility for a balance of concrete and abstract thinking.

Discussion among the students and the teacher should lead to a determination of what constitutes a cleaned-up classroom and what the responsibilities of the students are concerning it. Is it their duty to sweep the floor, or is this a service performed by a janitor? Conditions in the laboratory that frequently have been unsatisfactory--a chip-covered drill press or unreturned tools--should be identified as trouble spots. In this way the situation is examined so the students will have an opportunity to determine what is in the problem and what is excluded.

The goal of leaving the room in a clean and orderly condition should be defined. The students should be motivated by realization that there is need to leave the room in order at the end of each of their class periods. The discussion could then turn to suggestions that might be developed into tentative solutions. The teacher may be helpful by asking questions that will bring student attention to the causal conditions in their situation. Examination of the situation for relatively fixed conditions, such as placement of responsibility for clean-up, may produce suggestions. Exploration of students' calculated guesses may bring forth other suggestions.

The consequences of helpful suggestions should be explored and developed. A suggestion that the last person to use each piece of equipment should clean it, and return it to its proper place, can be developed and tested rationally and imaginatively. This suggestion may bring into the open the facts that some students habitually forget to care for equipment and that others wilfully avoid their responsibilities. Relevant hypotheses, thus, can be developed by a group of students using reason and imagination.

At this point, if progress is slow, it may be wise for the teacher to change the subject, or to turn the attention of the class to some other activity, giving the students time and opportunity for incubation of ideas. When the teacher turns again to discussion of the goal of a clean and orderly room, a reasoned plan may have been developed by one or several of the students. It may appear to be promising, and the class may be favorable to it. The plan (reasoned hypothesis) may then be tried out experimentally at the close of the next few class periods. If the plan should fall short of being an adequate solution, further attempts to develop a better plan should be considered. Even though a plan may not succeed, however, the experience of the students developing it should prove to be worthwhile in improving their problem-solving abilities.

Problem in Tool Process Selection

Assume that two seventh grade students in their first industrial arts class are constructing a box hockey game according to a plan they selected and modified. They are ready to cut-out semicircular holes along the edges of the plywood dividers. They have a problem of cutting wood along a curved line. The background of experience they bring into this situation varies greatly. One student can recall only a regular handsaw. He wants to make a few straight cuts with a handsaw and then round the edges with a file. Another student recalls having used a coping saw in elementary school to make curved cuts in styrofoam, and he suggests using a coping saw to cut the semicircular holes.

Recognizing or anticipating this problem, the teacher should call a meeting of the students who are building box hockey games and ask them how they propose to cut the semi-circular openings. In the discussion that follows several tools may be mentioned by students and teacher. The teacher, with the participation of some students, then should briefly demonstrate the processes involved in using suggested tools. He should stress safety of the tool user, care of tools, and strong or weak features of each process. The teacher may conclude his demonstration by asking questions that will help the students review advantages and disadvantages of all the suggested processes. He should leave the judgment of alternative processes and the making of decisions to the students.

It is common practice for teachers to designate directly the best tool process for a job in situations like the preceding one. They may do so because of expediency, or because they believe students should be told the best ways of doing things so they can build foundations of basic knowledge that can be used later. This approach, however, does not do much to encourage student understanding of why one tool is better for a particular job than another. It seems to circumvent an excellent opportunity for complete teacher-guided student experiences in problem solving that youngsters can successfully manage. Furthermore, direct teacher information amounts to pre-perfection of physical and ideational aspects of learning activities that reduce the potential of a problem-solving situation.

A question was cited earlier in this study as to when students are ready to solve problems in industrial arts classes--whether direct schooling in basic subject matter needed for solving problems should precede experience in solving problems.[2] A fairly common view held by many industrial arts teachers is that students, before being allowed to make decisions on their own, must be prepared through carefully planned and directed experiences in basic tool processes, related information, and planning procedure. The key argument of these teachers seems to be that the more enriched a student's experiential background is in a problem area, the more likely it is that he will be successful in solving problems later in the same area. Teachers having this point of view reason that one cannot solve problems in a vacuum. They feel that as much as is possible should be taught in cabinet making operations and related information, for example, before students should be allowed to choose their own problems involving wooden furniture construction. The students will then be equipped with necessary skills and information before they start constructing projects.

---

[2]Chapter I, p. 4.

An argument counter to the foregoing point of view is that such a plan of action, if carried to its extreme, would have little or no potential for provoking improvement of problem-solving ability because students theoretically would know all the basic answers. All would be familiar to them, and almost habitual. According to the definition of an authentic problem-solving situation, a problem very well might not exist and there would be little challenge to the students.[3] A question exists as to whether there would be time in the course of instruction for the teacher to do more than cover all the information regarded as basic. Would there be any time left for problem solving? Also, such instruction seems to be carried on without a unifying purpose to make it meaningful to students. The students' learning is apt to be atomistic, and their knowledge short lived.

Some teachers believe that student problem solving should be stressed from the beginning, that problem-solving method should be the teacher's basic approach to accomplish the improvement of his students' problem-solving abilities. This approach also has questionable aspects. Problems that the students decide to undertake may involve too much that is unfamiliar or completely strange to the problem solvers. They may be puzzles, almost impossible to solve by the students who choose to solve them. Or problems may involve

---

[3]Chapter I, pp. 12-14.

too little that is unfamiliar. Neither problems that involve too much nor those that involve too little that is strange to problem solvers meet the criteria for a true problem situation as established in this study.[4] Such problems do not allow for a balance of the old and the new. They either involve too much that is already part of students' experience, or they involve too much that is outside the experience of problem solvers. It is seriously questionable, for example, whether seventh grade students should engage themselves as their first experience in industrial arts in designing and building midget go-cart racers.

It would be the result of fallacious reasoning to assume an either-or position about students' need for subject-matter information and experience in solving problems, or to assume the precedence of one or the other. Both are needed. It would be impossible for students to achieve improvement of their problem-solving abilities without both. Students can not solve problems in a vacuum, nor can their problem-solving abilities be improved unless they have experience in solving problems.

Regarding the question as to whether instruction in basic subject matter should precede experience in solving problems, it is suggested that students can solve problems from the beginning if the problem complexity is commensurate

---

[4]Chapter I, pp. 12-14. Also Chapter IV, pp. 94-95.

with the experiential level of the students. Appropriate problems should involve some of the student's prior knowledge and they should involve some information or skill that is new to him. Several of the problem illustrations in this chapter would be suitable for beginning industrial arts students--especially the problems having to do with social living and with selection of plans, tools, and materials. Provisions should be made by the teacher for students to acquire new information necessary for solving their problems. New information can be provided by the teacher's timely guidance and instruction, and by relevant reference materials and other resources. The scope and depth of student problems can be adjusted as the students' experiential background grows. Always, problems should involve elements of the familiar and of the strange.

Problem in Materials Selection

Assume that a group of students interested in making target boards for dart-throwing games are engaged in the problem of selecting material for target boards. A difference of opinion among the students may arise as to whether they should use fir plywood. One student may comment that it is an unsatisfactory material because it is difficult to remove darts from plywood. He may suggest that three-quarter inch insulation board would be more suitable for the purpose. The teacher, who has been listening to the student's remarks, may ask his reasons for his suggestion, and may thus encourage him to think through the implications of his position. The teacher also may encourage several students to try out their reasoned positions by testing different kinds of boards with darts, thus promoting experimental verification of reasoned hypotheses. After testing samples of plywood and insulation board to determine which would be better to use for a target board for darts, some students may be surprised to find that certain areas of the plywood do not readily support darts unless they are thrown with considerable force because of the hard, dark growth rings in the wood. This discovery may call the attention of the students to another criterion of selection of dart-board material--its capacity to support darts, even when they have been thrown with little force. This situation is an example of how experimentation may produce problem redefinition.

The students may observe that the surface of the insulation board chips and slivers after many punctures. They may discover through experimental testing that the damage the darts do to insulation board dulls the appearance of the painted target. The results of the students' experience probably will show them they need to find a better material for their purpose than either plywood or insulation board. They now know they must consider the capacity of the material to hold darts, whether they are tossed lightly or with force; they must consider the durability of the surface of the material; and they must determine whether darts can be easily removed from the material. With redefined criteria, the students can test additional materials.

This situation is an example of a problem that is better defined later in the problem-solving process than at the beginning. It illustrates that the pattern of solution does not necessarily follow sequential models of process.

The teacher can introduce practices in experimental testing procedures, such as control of variables, sampling, replication, and systematic data recording. Here experience in observation and data collection is in context with an over-all purpose.

Problem in Quantity Production

There are two primary objectives in the sample learning experience that follows. They are improvement of student problem-solving abilities, and development of student appreciation for and gain in knowledge about the quantity production process in the production of consumer goods.

Assume that the chief activity of an industrial arts class is the production in quantity of some product. Together, the teacher and class decide to stencil by screen process school emblems on sweat shirts, T-shirts, and jackets.

The class is made up of eighth grade students in the second semester of general industrial arts. They have a variety of somewhat vague ideas about quantity production.

The teacher should attempt to sharpen their concepts of the social significance of quantity production, its basic features, and the detailed planning involved through such means as a trip to a local manufacturing plant where students can observe quantity production and ask questions about it. Also, he may provide the class time for reading short articles about quantity production. A film on mass production may be shown. All of these contributions can help students to develop a background of meaningful understanding of the role of quantity production in manufacturing consumer goods. Student participation in quantity production of consumer goods, however, is especially important.

The class had introductory experience with silk screen process when the students made posters early in the term. So the group has some understanding of the process; but silk screening on cloth combined with applying felt flock to the screen printed emblems is new to the students. Hence, elements of both the strange and the familiar are present in the problem.

Class discussion of the production of stenciled garments leads students to the identification of several sub-problems. Developing an acceptable design, gathering proper and sufficient materials, preparing stencils, and organizing the group for production are identified as problems needing attention. Committee action is decided upon as the best method for finding solutions to problems in each area. Liaison persons are needed to co-ordinate committee action.

The students responsible for preparing stencil films and sticking them to screens should have practice in these delicate tasks using scrap materials. This practice is worthwhile for students to have before they attempt to cut and adhere final stencils. Student practice should also be encouraged in printing on cloth with fibre and weave similar to those of the garments to be used later. Here practice is being carried on in context with a real need, as part of a whole situation.

In an early planning session, the teacher asked the group responsible for gathering materials to enumerate the conditions that the garments would be subjected to in the normal course of their use. Thus, those students had learned of the need for special silk screen paint and felt flock that is waterproof and colorfast. The teacher also supplied the group with reference books and materials catalogues, and made arrangements for the students to visit a local businessman who had once operated a screen process shop. A balance was struck between the teacher's providing too little and too much information. He helped the students to take proper steps in solving their problem of getting together necessary materials.

The liaison students who are responsible for co-ordination of all the processes involved in the total problem need periodically to appraise the progress of the various committees, to stimulate improvement of communication between groups, and to identify previously unforseen problems. They may find that charting the delegation of responsibilities of all members of the class facilitates communications.

When the problem is concluded, the teacher should lead the students in an appraisal of their learning experiences. They should generalize on the processes and techniques they used both successfully and unsuccessfully in solving their problem, and they should fix learnings relative to the nature and importance of quantity production in our society.

Problem in Designing a Holding Fixture

Assume that a senior high school student who is building a motor scooter frame is faced with the problem of securing in position two pieces of tubing preparatory to welding them. It is important that the pieces meet at a particular angle. The student must discard his first idea of holding the pieces of tubing together with his hands, because examination of the conditions in his situation leads him to realize he must make an identical weld of two other pieces of tubing. He then may attempt to work out his problem by using a series of clamps. He may not be able to hold the tubing securely and he becomes dissatisfied, because he may realize that it will be difficult for him to duplicate the clamp method later, for his second weld. Reflection on how to solve his problem produces no new suggestions, and he finds that his efforts are blocked.

At this point he may call on the teacher for help; and the teacher should ask him to review the conditions of his problem. The teacher's questions should lead the student to explain his attempted solutions and his reasons for attempting them. Through verbalizing a review of his problem, the student may himself come upon a new suggestion. Or the teacher may have to try to remove the student's block by offering suggestions that may shift the student's point of view or set. The teacher could ask, for example, if the pieces of tubing to be welded could rest on the same plane, or if they could be fastened to a single plane surface.

Accepting the teacher's suggestion the student may develop it thoughtfully, reasoning that he could layout the angle on a sheet of plywood or steel. He could place cleats along the lines he drew on the plywood and clamp the pieces of tubing in place against them. He then may test his reasoned plan in actual conditions, gaining almost immediate feedback of the consequences of his thinking. Feedback constitutes one of the strengths of industrial arts learning experiences for improving problem-solving abilities. Direct and immediate experimental testing of reasoned hypotheses helps to make a complete problem-solving experience.

Summary

In this chapter an attempt has been made to apply the principles developed in this study to the designing and conducting of learning experiences in industrial arts. Several illustrative learning experiences were described. The major objective of this study, namely the development of principles for guiding industrial arts teachers when designing and conducting learning experiences which will improve student problem-solving abilities, has been achieved.

CHAPTER VIII

SUMMARY

Purpose and Procedure

The primary purpose of this study was to develop principles for guiding industrial arts teachers when designing and conducting learning experiences for improving student problem-solving abilities. The findings, however, were equally valuable for teachers of other subjects.

The principles were developed as the result of careful examination of (1) writings of selected authorities in education who have dealt with problem solving as an objective and method of education, (2) the writings of educational philosophers John Dewey and William Kilpatrick, and (3) experimental research studies in problem solving. This study is best classified as philosophical. It may also be identified as synthetic research since its purpose was to focus on a central problem the concepts and findings originating in a number of studies.

In Chapter I, the purpose of the study was identified, the method of research explained, and the problem-solving situation defined. The theoretical base for problem solving as an instructional objective was described in Chapter II. In addition, a system for deriving educational goals was investigated. The roots of problem solving as an objective were examined, and a broad statement of the objective was translated into a series of definitive phrases descriptive of desired behavioral outcomes. A rationale was then developed for the contribution of industrial arts instruction to this goal.

In Chapter III, problem solving was treated as a method of teaching and learning. The method was described and its strengths cited. Emphasis was given to the inseparability of objective and method. The conditions of educative experiences were then developed as a base for identifying more specific principles.

In Chapter IV, the writings of John Dewey and William Kilpatrick were examined to locate philosophical concepts which resulted in the listing of a number of principles. Reports and summaries of experimental research were examined in Chapter V to isolate germane principles.

Both sets of principles evolving out of the investigation of the two sources were merged in Chapter VI. These were organized around Dewey's phases of reflective thinking; plus a category for principles too general and broad for inclusion in any one of the five phases. The resulting principles were then applied to the teaching of industrial arts in Chapter VII. Representative teaching-learning situations were described in some detail; and emphasis was given to showing the application of the principles. The chief task of this final chapter is to present some major conclusions and further recommendations for additional research.

Conclusions

Since a substantial number of principles were developed in this study, it is not appropriate to summarize them in this chapter. Instead, the reader's attention is directed to the last part of Chapter VI where they appear in concise statements. However, the following major principles were developed and supported by rational and authoritative means:

1. The greatest gains in improving student problem-solving abilities can be effected when the teacher consciously plans learning experiences with the goal of improving problem-solving ability in mind.

2. The improvement of student problem-solving abilities is best accomplished by the teacher's regulating indirectly the conditions which guide it.

3. The exposure of students to direct experience in attempting to solve real-life problems through the use of problem-solving method is the teacher's most appropriate way to achieve improvement in problem-solving abilities.

4. In designing and selecting problem situations suitable for improving student problem-solving abilities, it is important that the teacher make the distinction between genuine problems and those which are not. The following criteria serve to define authentic problem situations.

   a. There should be an objective in view.

   b. There should be something blocking the objective.

   c. There should be awareness or consciousness of the goal and blocking obstacle. There should be intellectual activity.

   d. There should be a high degree of subjective identification or motivation.

   e. Problem situations at both ends of a problem difficulty continuum, which range from the extremes of the completely familiar (rectifiable through unthinking, habitual response) to puzzles (solvable through accident, rational means being of little consequence), are less desirable problem situations than those in between and should be minimized.

5. It should be recognized that problem solving is both a method and an objective in education. It

is a means for achieving numerous educational objectives, including improvement of problem-solving abilities. It is also an end or an objective of education because of its significance as a method in living and learning.

6. Problem-solving method is practically synonymous with learning, and there are indications that problem solving is generally equal or superior to other methods of learning.

7. Learning experiences, to be educative, should provide for further growth, for interaction between individual and environment, and for intelligent managing of ends and means. They should be continuous with past and future experience, should have both active and passive elements, and should include reflective thinking.

These major principles were supported by some seventy other principles. These principles were more specific and were concerned with methods, techniques, and devices for guiding teachers when structuring learning experiences. The seventy principles were organized under the five phases of problem solving: source and nature of problems, problem definition, occurrence of suggestions for development into problem solutions, development of hypotheses by reasoning, and testing hypotheses by experimentation. They were followed by general principles, which because of their nature did not lend themselves to inclusion under any particular phase of problem solving.

The principles were regarded as tentative rather than final. Their validity was dependent upon the limitation of a number of factors: the scope of this study, the reliability and accuracy of the sources, and the ability of the researcher.

Additional limitations may have resulted from the confining of research for principles from educational philosophy to experimentalists Dewey and Kilpatrick; the exclusion of research directly concerned with principles for developing creativity; the elimination of principles for evaluating improvement of problem-solving abilities; and the barring from consideration of the problem of establishing ethical principles for determining appropriate ends upon which to focus improved problem-solving abilities.

A primary strength was the inclusion of principles resulting from both philosophical and experimental research. A more efficient set of principles resulted from the extraction of contributions from both sources, rather than concentration on only one. Evidence demonstrated that they reinforced each other and consequently a more reliable set of principles emerged.

Additional Research

This study suggests the need for further research in a variety of directions.

1. A study of available research in the field of creativity may produce findings related to this study and thereby help clarify the relationship between creativity and problem solving.

2. The development of principles for evaluating problem-solving ability needs attention if teachers are to be able to determine degree of effectiveness toward achieving this objective.

3. Additional experimental and philosophical research should be conducted to further test the validity of a number of the principles identified in this study.

4. An examination should be made of other philosophical and psychological positions to determine the extent to which the principles developed in this study would coincide.

The objective of this study has been accomplished in that a set of principles has been developed for guiding industrial arts teachers when designing and conducting learning experiences to improve student problem-solving abilities.

It is hoped that the findings will be useful to industrial arts teachers as they seek to perfect their contribution to the education of the nation's youth. Since the concepts and principles developed have a degree of universality, they should be of value to teachers of other subjects.

APPENDIX A

HISTORICAL REVIEW OF THE LITERATURE OF INDUSTRIAL ARTS TO DETERMINE CONCERN FOR PROBLEM SOLVING AS A GOAL AND METHOD OF INSTRUCTION

The research for this review of industrial arts literature was undertaken with a view of determining the degree of interest in problem solving that has been manifested in the literature of the field during the past thirty years. Materials were examined for indications of concern for problem solving, both as an educational goal and as a method of instruction. Attempts by writers in the field to relate problem solving to such foundation areas of education as theory of learning, philosophy, and sociology were noted.

The sources investigated were journals, textbooks, yearbooks, and doctoral dissertations in the area of industrial arts education. Articles in journals proved to be the most beneficial source of information because the current ideas in the area were thoughtfully reflected there.

A bibliography of publications about industrial education; (7) a bibliography of dissertations in industrial education, 1939-1959, (31) supplemented by two reports on recent research in industrial arts; (48; 67) and the ninth yearbook of the American Council on Industrial Arts Teacher

Education (61) were consulted to locate significant research.

This review is arranged chronologically in three periods: 1930-1940, 1941-1950, and 1951-1960. Many ideas that were treated, and that are pertinent to this study, will be discussed briefly here.

Decade, 1930-1940

Robert Selvidge, in 1934, observed the importance of reflective thought and the role of industrial arts in its development.

> Reflective thought, or reasoning, and the use of tools in construction are the principle activities which distinguish man from the lower animals, and much of such thought is concerned with planning and doing. Creative thought is essential to man's progress; creative doing is essential to his life and comfort. It appears, therefore, that teachers are neglecting one of the most important phases of man's life if they fail to develop his abilities in planning and doing through such experiences. . . . The experiences in the industrial arts field are designed primarily to develop the ability to plan constructively, which also involves reasoning, and to use tools. (46:29-30)

Several other writers of the period included improvement of problem-solving abilities in statements about industrial arts objectives and trends. Some of them were Jessie Fox, William Hunter, Arthur Mays, Homer Smith, William Bawden, and Elmer Christy. (17; 30; 39; 49; 5; 11)

Charles Bennett was reported by Albert Siepert to have emphasized as early as 1917, freedom for discovery, with minimal teacher direction, in student selection of tools and processes in construction. Bennett said:

> Children must be allowed to depend upon their own thought and judgment in doing things. Let the children see, think, and do; later may possibly be the time for explanation; surely not before. There is a discoverable reason why one method is better than another, if it be better; one tool more adapted to the purpose in hand than another. If we wish children to develop a reasonable judgment in all things, as we surely do, we must on no account discover for them what they can discover for themselves. (47:93)

Selvidge, who also wrote about the importance of planning and problem solving, advocated much more teacher direction than did Bennett, according to Siepert. Selvidge stressed "active mental effort by the pupil after he has had some practice on the more fundamental and generally used operations." (47:93) The student should then be challenged to plan a job, listing steps in order of performance, and listing tools and materials required. Siepert summarized the positions of Bennett and Selvidge as follows:

> While some would leave the pupil to his own resources in the discovery of tools, materials, and processes, Selvidge places emphasis upon analysis and planning by the pupil, and responsibility by the teacher for checking both the analysis of the job and the proposed plan of work, as well as for supplying all necessary information and for the demonstration of new processes. (47:94)

An outline of a method of learning in industrial arts, credited to Selvidge by N. B. Grinstead, recognized the problem-solving method of learning.

1. The student makes a clear and definite statement of his project to the teacher.
2. The student analyzes the job, selecting the operations involved, the information required, the facilities available, and considerations of other

work being done in the same shop. He selects materials and designs which are suitable, estimates amounts, figures approximate costs, etc.
3. The student organizes his work according to the analysis he has just made.
4. The teacher presents any information which the student requires, gives demonstrations of new processes, etc., and checks on the ability of the student to proceed in the light of his understanding and planning of the job.
5. The student does <u>his job</u> according to <u>his plan</u>, if he meets difficulties, he may secure help from other students or the teacher, but the work is primarily his own.
6. The student checks his results according to a scale or standard with which he is familiar. The teacher checks with the student. Checking is a progressive process during the entire job.
7. The student reports to the class on how the work was done, difficulties and how they were overcome, better means of doing the work, time required, and cost of the article. (26:293)

The teacher is the source of needed information in Selvidge's plan, and since he checks the student during the entire job, it is apparent that his role is more like a director of learning than a guide.

Two periodical articles by Vern Fryklund, dealing with reasoning and problem solving, appear to cover essentially the same ground, even though there was a span of nearly seven years between their publication dates. (21) (22) They represent a concerted effort by an industrial arts educator to aim industrial arts instruction toward improvement of problem-solving ability in a manner consistent with then current principles of psychology.

He pointed out the importance of problem solving as a goal for industrial arts instruction. "Inasmuch as the problems of life are not accompanied by solutions, the only way we can arrive at a particular solution is by a process of reasoning," he wrote. "It is, therefore, the school's responsibility in every creative activity to provide opportunities for development of problem solving abilities." (21:256) He also indicated he thought improvement in student problem-solving techniques should be directly planned for in teaching; that such improvement should not be considered as merely a concomitant outcome of instruction.

Regarding the psychological basis of the problem-solving method of teaching, Fryklund seemed to reflect two schools of thought--associationism and behaviorism. His acceptance of principles of associationism is represented by his statement that "there must be past experiences, an apperceptive basis, from which to draw the combination of patterns needed in the solution of a particular problem." (21:256) His acceptance or behaviorism is made clear in the following statement.

> When certain outcomes are sought in a teaching situation, proper stimuli must be provided to bring about the desired results. If the outcomes are to be uncontrolled and left to chance, there is little need for choice of stimuli. Therefore, if there are fundamentals involved in a shop activity, . . . then definite consideration should be given to planned instruction. Proper stimuli should be provided to bring about the desired performance. (21:255)

Fryklund stated unequivocally that problem solving cannot take place in a vacuum, that the student must have a background of experience to draw upon. He declared that learners must be taught fundamentals early in their experience; and he applied this idea to the teaching of shop work, identifying as fundamentals, common skills and technical information. After some background of experience in shop work, Fryklund wrote, the student should be allowed to solve problems in planning procedure for constructing things. He observed also that "the learner should plan his procedures, beginning with the first shop experience." (22: 226)

An inconsistency may appear to exist in these statements, one of which called for instruction in fundamentals early in preparation for problem solving; and another which called for planning with the first shop experience. The key may be in his interpretation of the meaning of planning. If he viewed planning as student-initiated and -directed problem solving, then there is an inconsistency, since students do not have the advocated background in fundamentals when they begin their first shop experience. If he viewed planning as teacher directed in which the teacher familiarizes the students with his preselected procedure, planned to include certain fundamentals, then he is consistent. A danger exists, however, if he meant to cover the fundamentals before having students solve problems, because the teacher may never finish covering all that he regards as fundamental. If his statement that planning should begin with the first industrial arts experience is interpreted as including introductory experience in decision making, the danger may be overcome.

An important observation about the opportunities for student thinking in industrial arts classes was made by J. A. Starrak. He said that "industrial arts work abounds in opportunities to exercise all three types of thinking involved in the intelligent solution of the practical problems of life; namely, reasoning, judgment, and creative thinking." (54:26) He argued that thinking ability is developed by thinking; but he added that teachers often rob students of opportunities to participate in thinking by doing it for them, when he wrote:

> In the performance of any task of educational value there are two steps or stages. The first is the planning stage. The decision as to size, design, the best materials to use, tools, equipment, processes and methods of instruction to employ, and the preferred order of work. All this is mental, and should be done before any actual physical work is attempted. The physical carrying-out of the plans made constitutes the second stage. Now, of these two steps, the first very obviously possesses much greater educational value. Yet, we teachers, in our anxiety over the quality and amount of physical work done, often rob the boy of participation in the thought processes involved in the first stage, for we supply him with plans, specifications, lumber bills, and detailed instructions. It is obvious that one cannot teach another to think by doing his thinking for him. This is perhaps one of the greatest sins of teachers. (54:26)

Starrak seems to have made a sharp distinction between mental and physical activities, a position inconsistent with field or Gestalt psychology. Starrak seems to have implied that the physical carrying of plans is devoid of opportunities for critical thinking and problem solving.

William Stone commented on a trend in industrial arts instruction away from mere training in the mastery of isolated skills and information toward instruction related to the needs of life and demanding student initiative and problem solving.

> Here the emphasis is upon . . . development of student initiative, problem planning and solving ability.
> . . . .
> However, as a unit of cooperative purposing, planning, executing, and judging, the total enterprise becomes a social participation, cutting across many areas, if not all, of institutional life. In such an undertaking, all types of intelligence are developed in unity, with especial emphasis upon social consciousness. (55:137-138)

Stone suggested an awareness of Gestalt psychology, which was becoming more prominent in the area of education in this country in the Thirties.

Discussing transfer of training, John Friese commented on the importance of method in the teaching of industrial arts, mentioning specifically problem-solving technique.

> The important thing in connection with transfer is to recall that the way a teacher teaches industrial arts is more important than what he teaches. He must also consciously direct pupils' attention to the procedures that they use in solving a problem. (19:1-5)

Using Dewey's five phases of reflective thinking, Theodore Struck defined his concept of problem solving and illustrated it with an example dealing with the designing and constructing of an article by students in an industrial arts class. (58:336-342) He explained how problem solving is learned through trial and error, imitation, hints and suggestions, and analytical thinking. In his opinion, the most worthwhile way to learn problem solving is through analytical thinking. He emphasized the importance of teachers developing student judgment or critical thinking in the areas of quality, quantity, relationships, time and speed, and socio-economic values. Struck's treatment of problem solving seemed to be one of the best of the decade by an industrial arts person found in the research for this study. Yet it was too brief to be an effective source for a teacher interested in learning teaching techniques for improvement of student problem-solving abilities.

Siepert wrote that Bennett, in 1917, described what he called the "inventive method," which seems to approximate what we currently refer to as problem-solving method in industrial arts.

> The inventive method begins, not with something planned ready to make and materials all selected, but with a conscious need for something to serve a known purpose and a desire to make something to supply the need. The procedure by this method is: first, to know definitely the conditions to be met by the thing to be made; second, to invent or design the thing to fulfill the conditions; third, to select materials and (fourth) to make the thing designed. From beginning to end the mind is centered on the thing being made and whether it will serve its purpose; the process or producing the thing . . . is here given secondary consideration. . . . In this method, then the teacher is more an inspirer, a counselor, than a boss who makes demands. (47:89-90)

Bennett later shifted the label from "inventive method" to "creative-method" when, in 1938, he described an industrial arts class footrest project. He placed emphasis on definition, analysis, and possible solutions of the problem. One may well question the choice of the restful footstool problem for adolescents, however, on grounds that it may be remote from their needs and active interests. Bennett could have carried "creative-method" farther to include questions about appropriate tooling processes.

> This footrest taught as a creative-method project has many possibilities. Such questions as the following will have to be answered: Why is this footrest more restful than many others? What measurements should be used to make such a rest that will be most comfortable for you? What kind of lumber will you use? What thickness of boards? How will you fasten the boards together? If you use tenons, how many will you use, and what will be their dimensions? How will it stand when not in use? (6:219)

Louis Hess, using a group approach, outlined a teaching procedure for stimulating student problem-solving abilities through the designing and constructing of solutions to problems. He made a definite appeal for a teaching technique to achieve this objective.

Using a wall shelf problem for illustration, he listed these points of procedure:

1. Secure interest
2. Provide illustration
3. Plan several types
4. Make preliminary plan
5. Criticize the plan
6. Make final plan
7. Follow plans in construction (28:34-37)

In the Thirties, most writers who gave examples of problem-solving activities in industrial arts dealt with the designing and construction of projects. Ray Soules, however, outlined problems in student self-government, which he counted as a value inherent in industrial arts. The variety of problems created by a number of students learning together and sharing the same physical facilities were to be solved through group effort with teacher guidance, according to Soules, thus affording opportunity for problem solving. Questions to be asked regarded responsibilities to be met, group organization to handle responsibilities, and designation of leadership posts and duties. (53: 202-204)

Summary of the 1930-1940 Period

There was some evidence of concern in the Thirties about the improvement of problem-solving abilities as an important objective of industrial arts instruction. Few writers defined the objective in terms of specific desired outcomes.

Theories of learning varied widely. Some educators supported the associational or the behavioristic schools of psychology. Others supported viewpoints based on field or Gestalt theories. Their differences of opinion were expressed in the teaching methods and techniques, and the student activities they advocated. Suggestions regarding student activities in problem solving, found in the industrial arts literature of the Thirties, include planning procedure, designing and building of objects, and facilitating student government. Evidence was found that, to some educators, problem solving was regarded as a method of teaching or learning.

A relationship of the roots of problem solving to the foundations of education appears to have been of little concern to those who wrote in the area of industrial arts during the Thirties. Only a few references were found that considered the relationship of problem solving to the sociological foundations of education. Those writers who seemed to recognize an affinity between problem solving and the philosophical foundations of education considered it only superficially. The relationship of problem solving to psychological foundations was noted by writers fairly often. The viewpoints, however, were eclectic. No evidence of significant research in problem solving by industrial arts persons was found.

Decade, 1941-1950

Glenn Warrick submitted a list of industrial arts objectives that he compiled from a distillation of literature in the area, to a group of industrial arts teachers, and asked them to rank the objectives in order of their importance. (62:287) The teachers ranked in fourteenth position "self expression and problem-solving attitudes: the stimulation of creative self-expression and problem-solving attitudes through encouragement and opportunities to plan and construct useful articles in suitable materials." They placed in ninth position "planning: the development of a habit of orderly, systematic procedure or abilities which assist in the intelligent planning of any task." (62:287) The objectives included considerations not related to problem-solving abilities; hence, the ranking of self-expression and problem-solving activities, and planning in fourteenth and ninth positions gives an indication of the relative importance placed on problem-solving objectives by industrial arts teachers at that time. Writing in 1946 about the emphasis on subject matter by industrial arts teachers, John Whitesel expressed concern that teachers were neglecting to teach subject matter as it related to the solution of everyday problems. (63:331)

"Skills and information are the tools used in creative thinking," John Friese wrote the same year. (18:88) After classifying the aims of teaching as the development in students of manual skills, appreciation of information, and thinking or problem-solving ability, he assigned primary position to the last aim. To him, development of student capacity for reasoning or problem solving was surpassed by no other educational goal. (18:89)

Friese believed that industrial arts was in a unique position to contribute to the educational aim of problem-solving ability. "No other subject, except agriculture," he wrote, "can approach it because of limitations due to equipment, housing, nature of content, and traditions in methods of teaching and class management." (18:89) He added that ability to capitalize on the opportunity to contribute to the aim of problem-solving ability depends on the teacher. "For a teacher to think through and plan <u>all</u> of a boy's experiences in industrial arts," he observed, "robs the boy of the driving force of interest and the great educational values that may result." (18:89)

Friese pointed out "the lack of provision for methods and vehicles" to support the problem-solving aim. "<u>Problem-solving experiences must be written into the course of study</u>," he declared. (18:135-136) The project method seemed to him to be the highest form of problem method. But he placed value on other activities, such as planning parts of assigned jobs.

Friese defined the project method of teaching as one which will give the student an opportunity to experience a seen need or a felt desire for an object, to form a plan for making the object or doing the job, to create the thing planned, and to judge the results accomplished. (18:137) When the "final result stands out as a correct or faulty physical product which he can judge by objective standards," he said, "the boy experiences something he cannot get from abstract problems." (18:138)

In a commonly used textbook in undergraduate methods of teaching industrial arts classes, Gordon O. Wilber emphasized the importance of the problem method as a vehicle for experience in critical thinking. (65:22-24) He commented that (1) students should be guided to select problems that challenge them, but are not beyond their abilities; (2) students should be given opportunities to solve problems themselves; (3) "it is probably more important, from an educational standpoint, that a child be able to plan his project correctly than [that] he be able to carry it out skillfully;" and (4) facility in solving problems is reinforced through success. (65:24)

In 1945, John Fuzak discussed psychological theory for improving reflective thinking abilities as an aim of industrial arts instruction. He explained how theory can be applied to class situations by suggesting a group-discussion approach to the planning procedure preliminary to student construction of a table. This approach, he wrote, is designed to place emphasis on the teaching objective of student achievement in planning, through reasoning or reflective thinking, the procedure for doing a job. (25:586) He predicted that industrial arts teachers would work toward such an objective when they became aware of its significance, and that they would "perceive many situations which can be utilized in stimulating thought of a reflective nature." (25:588)

The following year Emanuel Ericson commented about the division of opinion among teachers regarding problem-solving method in industrial arts instruction.

> Those stressing the need for problem solving would say: (1) The traditional methods in teaching manual arts have been too dictatorial; (2) modern educational theory places emphasis upon individual thinking and self-expression; (3) industry and business are looking for persons with initiative and originality rather than blind following of tradition and directions; (4) traditional methods and even skills are less important for the rank and file of industrial arts students than traits leading to character and general employability. In the opposite direction the following views might be held: (1) In most instances, mechanical work techniques and methods have been established through a long period of trial and experimentation, and to allow students to try to discover new and better ways is a waste of time; (2) for one person who will be in position to plan and originate work there will be ten who must follow explicit directions; (3) many students are more interested in following directions than in discovering methods for themselves and will lose interest if made to do their own planning; (4) following established methods is the best foundation for inventing new ones. (15:63)

A teacher's success in the use of problem-solving method, according to Ericson, depends on:

> (1) high initial interest on the part of the student in the activity undertaken, (2) a creative and inventive type of mind, (3) projects within basic experience and ability of the student, (4) reasonable length of time allowed for concentrated work or for completion of project, and (5) recognition of success or of promise of success on the part of the student. (15:43)

<u>Summary of 1941-1950 Period</u>

In the literature of industrial arts in the Forties, few writers were found whose ideas about problem solving differed markedly from those of writers of the previous decade. There seemed to be a general educational inertia, no doubt accounted for during the first half of the decade by the concentration of the nation's attention on winning World War II.

There is evidence that as an objective, problem solving was not ranked highly by the teachers in the area of industrial arts. This statement could be modified only if orderly, systematic planning procedures were interpreted as involving problem-solving abilities.

As a method, problem solving was recognized officially by its inclusion in the industrial arts methods textbooks published during the Forties. There was, however, wide divergence of opinion among industrial arts teachers regarding the desirability and the use of problem-solving method.

Decade 1951-1960

Fuzak summarized the purpose of general education as "the improvement and continuation of our democratic society [and] the promotion of adequate adjustment to a changing technology." (23:12) He said that development of problem-solving ability is an essential goal of general education and of industrial arts if the purpose is to be realized.

The critical thinking of students can be improved by their "actively tackling problems of increasing complexity" better than it can by their being taught the "abstract steps of scientific method." (23:13) Industrial arts, Fuzak pointed out, is well suited to contribute to the improvement of problem-solving ability through a problem-solving approach. In industrial arts, problems can easily be individualized; and tangible evidence of students' attempts at problem solving can be provided in the form of three-dimensional products which readily lend themselves to identification of flaws and strengths in student thinking. (23:13)

John Rowlett asked, "Why should rats be given greater challenges than industrial-arts students?" (44:7) In 1959, he wrote that there were industrial arts teachers "who insist that their students develop problem-solving by completing a rigidly prescribed series of pre-planned (if not pre-cut) projects." (44:7) He compared the potential challenge of such a learning situation with that of rats in a psychologist's maze, and he concluded that a rat was challenged to a greater degree than many industrial arts students.

> Undesirable as it may appear, the rat that is confronted by multiple paths leading to his goal--with opportunities for exploration, decision making, and problem solving--is presented with greater challenges for <u>its</u> level of intelligence than are students who must learn within the limits of a fixed series of projects.
>
> . . . .
>
> Our students should get consideration at least equal to their levels of ability, just as the psychologist challenges his rats. (44:19)

Rowlett stressed the importance of designing learning activities which challenge the potential of industrial arts students.

William Micheels, in 1958, prognosticated an increase in and clarification of problem-solving activities by 1970.

> A natural development will be the inclusion of more problem-solving activities in the learning process as opposed to rote learning which permeates so many courses. One of our jobs will be to provide more experimental and research activities having to do with the use of tools and materials in solving problems. A major breakthrough, already building up, will have occurred in this matter of design, with all that it implies. Our teachers of 1970 will have learned to treat design as a form of problem solving, a product of research, a way of feeling, rather than a series of mechanical rules for contour development and surface enrichment. (40:31)

Clarification of the relationship between design and problem solving was predicted in 1960 by Raymond Karnes, who indicated methods he thinks will be emphasized in the future.

> Design will be defined as problem solving, and this will be recognized as a part of the content drawn from technology. The methodology to be employed in industrial arts will accomplish the old purpose of providing creative and aesthetic experiences in a way not previously achieved. Research, investigation, identification and solution of problems, evaluation and discovery will characterize method. (32:7)

Donald Lux wrote in 1959 that industrial arts was in the forefront of a movement to increase emphasis on problem solving. He made the following significant statement regarding the contribution industrial arts could make to the goal of problem solving in general education:

> Greater recognition still needs to be given to the fact that the teaching of problem solving with contemporary materials, tools, and processes of industry, rather than with imaginary academic problems, is one of the valid justifications for the requirement of industrial arts as general education. (35:147)

According to Lux, the problem-solving method of teaching involves:

1. Active seeking of a pupil-teacher approved problem.
2. Having the pupil carry the primary burden in analyzing a problem, once it is identified, to find the most desirable solution.
3. Solving the problem, if possible, according to a pupil developed and constantly-evaluated plan.
4. Pupil-teacher evaluation of the result. (35:148)

The project method, he observed, was practically synonymous with the problem-solving method, it if made use of a strong element of self-direction by the student.

In 1956, Whitesel and Fuzak both stressed the importance of problem solving in industrial arts teacher education.

> Life is one continuous chain of encountering and solving of problems. The more one is able to use the scientific approach and technique in dealing with such situations, the more successful he will be in meeting the problems of life. (64:78)

> The impossibility of preparing a teacher with the answers for all of his problems is immediately apparent. The situations and problems confronting the teacher in today's schools are extremely perplexing, and since they are composed of seldom repeated combinations of factors, no bag of tricks . . . can possibly contain more than an infinitesimal fraction of the appropriate solutions. The creative teacher who has developed a degree of educational perspective through the problem-solving process is

> far better equipped to deal with his problems than the teacher trained to rely on a series of gimmicks. (24:220)

A milestone in industrial arts teacher education was reached the same year with the publication of the Minnesota Plan. (41) Various references were made to problem solving as an objective of instruction and as a method of learning. Two unique contributions of industrial arts were cited:

> 1. To help young people learn to solve problems by using the tools and processes of industry.
> 2. To help young people learn how industry uses tools, materials and processes to solve problems. (41:31)

Among the suggestions offered relative to theory of learning, problem solving was directly mentioned:

> Problem-solving attitudes and skills can be developed only by participation in many meaningful problem-solving activities.
>
> There is need for learning experiences which are primarily concerned with problem solving such as design courses and independent study programs.
>
> Each student should receive problem-solving experience in designing and producing a limited quantity of a product for a limited market. (41:33-35)

Calvin Street, discussed the importance of problem solving as a concern of general education and set up student problem-solving ability as a teaching objective. In 1956, he wrote:

> Since scientific method of problem solving is deemed the most valid way that human beings have discovered for solving problems, it becomes obvious that each person should develop, to the limit of his ability, skills in the use of this method. (56:178)

He said that learning which takes place in problem solving is different from that which results from rote learning. Knowledge acquired through problem solving is more apt to be available than knowledge acquired through rote learning, and is more useable when needed again. Street implied that problem solving as a method of learning facts and skills has superior characteristics. (56:179-181)

A significant article that applied psychological principles of learning to teaching for improvement of student problem-solving abilities was published in 1956 by Robert Swanson. The relationship of problem solving to learning was reflected in his comment that "some have gone so far as to say that problem solving and learning are synonymous." (59:243) In his article, he developed answers to three basic questions:

1. How do we motivate problem solving?
2. What kinds of activities and experiences can we provide to develop problem solving ability?
3. How do we provide meaningfulness and understanding? (59:243-245)

Speaking to an assembly of industrial arts teachers about problem solving and design Aarre Lahti, an industrial designer and educator, said:

> I can foresee a date which will be upon us far sooner than we dare believe, a date when our students will be primarily concerned with problem solving. As our society and technology become ever more complex our students cannot be provided with a package of skills adequate for future problem solving needs. However, if the student has been fortunate in his training, he will have acquired the how of problem solving. He will be able to analyze and recognize

> what skills are essential, how and where to seek them and then teach these skills to himself. Skills will be mostly self-taught. (34:7)

Lahti pointed out some concepts that he felt were important for teachers to be aware of if they hope to facilitate problem solving in their classes. They were cooperation instead of competition, relativeness of all things instead of absolutes, non-authoritarianism rather than authoritarianism in view points, sharing instead of possessiveness, openness rather than secretiveness, and willingness to make commitments instead of evasiveness and fear of being wrong. (34:6-7)

After stressing the increasing need for analytical, constructive thinking because of the growing complexity of life, Arthur Mays wrote in 1952 that the attainment of this objective was "largely a matter of method of teaching and instructional skill." (38:165)

Clyde Burns developed a technique for adapting the traditional demonstration method to a form suitable for developing critical-thinking abilities and consistent with the problem-solving approach to industrial arts instruction. The following paragraph summarizes and illustrates the technique he called "developmental demonstration."

> The developmental demonstration does not start with a known fact or skill, but begins in the situation confronting the pupil and attempts to reorganize his previous experiences in terms of a present situation. The reorganization process, guided by the teacher, seeks to reveal the place of new information. Through activity on the part of pupils,

> principles involved are discovered. In the case of the board and the problem of a smooth end grain, the board would be placed in a vise and suggestions called for. Such ideas as sanding, using a wood file or rasp, and planing with various planes would be presented. Pupils making the suggestions would be given an opportunity to show results of their proposals and the class would evaluate each method in terms of time, effectiveness, effort, and result. If splintering of an edge resulted from planing all the way across, the reason of the mishap would be analyzed, and changed procedures discovered. The entire demonstration would be actively participated in by pupils, and principles known at the start by the teacher would have been developed by pupils through his skillful guidance. End results are that the pupil not only possesses the information, but he now understands how the information was derived. Retention of knowledge for later use has thus been materially increased. (10:12)

Drawing courses in industrial arts, Lawrence Wright wrote in 1956, should reflect problem solving as it takes place in industry. From this idea he developed several suggestions for instruction in drawing. Foremost among them is "that a part of the work in drawing must be done on a problem solving basis rather than by simply copying line work exercises from the nearest book." (66:247)

The problem-solving method was advocated by Oval Harrison as an effective approach to industrial arts teaching. (27:23-24) He wrote that the development of problem-solving abilities is one of the greatest accomplishments of education. As requisites to problem solving, he suggested that (1) the student should have freedom of choice of problems, (2) the teacher should guide and advise, (3) the problem must be the pupil's, and (4) the problem must challenge yet be within limits of the student's ability.

Harrison explained that numerous problems are encountered by students in designing, planning, and construction activities in industrial arts. He believed that teachers should use the problem-solving method to a great extent; but he cautioned against its use in the development of exact skills when direct teacher instruction in correct method is needed, and when dangerous operations are encountered. (27:24)

If it were assumed that design problems offer opportunity for problem solving, which this writer did, then several articles on the teaching of design should be included in this review to indicate more fully the interest of the profession in problem-solving activities.

Ronald Bro conducted a survey among industrial arts teachers who were reputed to be authorities in design. He asked them to rank the effectiveness of several teaching practices currently in use for conducting experiences in designing. The results indicated that (1) design should be integrated with the construction of articles as contrasted with teaching design as a separate course; (2) students should make many freehand sketches when designing articles; (3) construction of the articles designed furthers learning; and (4) evaluation of the finished article as to function and appearance was a desirable activity. (8:291-292)

Jerry Streichler suggested that the methods and approach of the industrial designer should be examined by industrial arts educators because "it is the work of the industrial designer that . . . suggests a coherent problem-solving approach deserving consideration." (57:288) He observed that understanding of the designers work could contribute to a number of industrial arts objectives and that "project development in industrial arts could follow an approach similar to the one used in product development." (57:316)

In 1957, Herbert Anderson equated problem solving with designing and advocated that they be taught on a continuous basis. He analyzed designing into several stages--establishing a need, analyzing function and appearance, research, sketching, model making, and summarizing the design in form of a working drawing. (2:211-214)

Wesley Sommers made an excellent contribution to the stimulation of interest in and better understanding of activities in design through his articles that appeared in School Shop and Industrial Arts Teacher. An early article explained designing as planning with a purpose, or problem solving to fulfill a need. (51:10) In the same piece he explained that "actual designing by students may have to wait until basic skills and knowledges have been developed . . . because students cannot do actual problem solving in terms of tools and materials that they do not understand." (51:10)

In a later article Sommers made specific suggestions regarding a wide range of activities involving design. (59: 9-11) Examination revealed them to be fertile ground for gaining learning about problem solving.

In another article on design, he presented a flow chart showing the design process which, when analyzed, followed closely the phases of problem solving. (52:12)

Arthur Anderson and George Ferns in a periodical article published in 1959, explained specific activities involved in designing and problem solving. Their aim was to share with other teachers planned learning activities they thought to be successful for providing experience to students in problem solving. (1:10-11) In a later article, with problem solving method in mind, they dealt with a series of stages in designing solutions to problems. Careful teacher planning, they suggested, can give beginning students opportunities to engage in problem-solving and designing activities even though the students have had little prior experience with basic tool operations. (16: 12-13, 42)

Explaining the role of the project in industrial arts, Ivan Hostetler wrote that projects should start with problems and that they "should involve the student in planning, designing, problem-solving, production and evaluation." (29:25)

The following criterion for determining the educational appropriateness of projects was suggested in 1953 by H. A. Anderson and K. T. Olsen:

> Does it provide problem solving? Every project should provide some opportunity for the student to plan some decision--simple or complex. Perhaps, the problem will be as simple as selecting two paint colors for his fishing plug which he turned on a lathe; or it may be as complex as arranging the grain pattern, color and direction of walnut stock prior to gluing up for a dining table top. (3:5)

Lux cautioned industrial arts teachers that individual project design is not the only method for teaching problem solving.

> The growing emphasis on teaching problem solving has caused some to look upon individual project design as the answer in industrial arts to the need for promoting creativeness and for providing experience in problem solving. This is an easy but inadequate solution. The experimental outlook and opportunities to use initiative must pervade the entire program, not just the few days of designing projects. (36:145)

Talmage Young recommended the group project as a method involving problem-solving opportunities and suggested its use as a beginning experience in industrial arts classes. (68:27-29)

Many writers, when describing problem-solving activities in industrial arts classes, have used as illustrations situations in which individuals are engaged in some phase of designing, or constructing physical solutions to problems. Joseph Duffy wrote about a group problem-solving activity of a non-physical nature in which students developed democratically a personnel plan for handling various functions that arose in their industrial arts class. (12: 296)

Research and experimentation as activities in industrial arts have been used in the field on a limited scale for some time. Recently, these activities have received considerable attention. Their use in industrial arts classes is based upon teacher interest in the educational goal of improvement of student problem-solving abilities and upon need to reflect the increasing importance of research and experimentation in contemporary American industry. A periodical article by Donald Maley developed a rationale behind research and experimentation activities in industrial arts classes, and wrote of the successful experiences of a junior high school teacher and his students. (37:12-16)

Arthur Earl, in 1960, described research and experimentation activities as a problem-solving approach to education. "The students and teacher, together, form a technical team to define the problem, structure the procedure, conduct the experiment, and record the findings." (14:23) He recommended a team approach as being particularly useful in the selection, definition, and development of research problems.

There has been a paucity of instructional materials available to teachers interested in making use of research and experimentation activities. Earl's recent book provides a helpful source of ideas for teachers and students. (13) It includes a variety of suggested topics for investigation. With the availability of Earl's book, however, teachers should take care not to follow its form slavishly or the spirit and potential of the experimental or problem-solving method will be diminished.

A dissertation by Clyde E. Burns shows he has done a significant research study in the field of problem solving in industrial arts. (9) His was the only thorough attempt found to determine the extent to which the problem-solving approach has been used in secondary school industrial arts programs. He described problem solving as an educational goal and as an educational approach, and he used them as basic criteria for obtaining evidence about the use of the problem-solving approach in Florida high schools. He found that:

> Development of problem-solving ability was not the primary concern for most Florida industrial arts teachers in the selection of instructional techniques. Most common practice was the use of techniques of all levels of excellence, with a tendency toward most frequent use of mid-level practices. Very few teachers were doing an outstanding job in the development of problem-solving ability through the approach described in this study. (9:696)

He also found that:

1. Teachers were successfully utilizing pupil interest as a basis for selecting projects but that immediate interest was often assumed to be synonymous with a personally challenging problem situation. (9:695)

> 2. Much of the plan-making involved no formulation of hypotheses for the solution of a problem. . . . The making of a plan was usually secondary in importance to the construction of the project.
> 3. The freedom with which pupils were permitted

> to select tools and materials for working out problems was generally more limited than the problem-solving approach demands.
>
> 4. The most frequent technique by which pupils gained information . . . was a demonstration by the teacher. . . . Very few teachers depended on the pupils to initiate the search for information. (9:695-696)

5. Development and operation of pupil personnel systems was not considered as a cooperative problem-solving activity. (9:696)

6. Predominant evaluative techniques were teacher centered. (9:696)

A 1960 doctoral dissertation by Ronald Baird considered the philosophy of John Dewey as it applied to industrial arts teacher education. (4) Much attention was given throughout the study to problem solving and related topics, with particular consideration to problem solving as both an objective and a method.

Clyde Keener, in 1959, observed the behavior of high school students in an industrial arts woodworking class. (33) His observations were compared with the outcomes listed in French's Behavioral Goals of General Education. (20:34) Student behavior, as observed by Keener indicated a contribution to goals of general education in many areas, including the attainment of intellectual growth and development.

Willis Ray, John Rowlett, and Jerome Moss, Jr., all completed their doctoral dissertations after conducting separate research studies comparing two methods of teaching industrial arts content. Ray's study,

> Was an attempt to provide additional experimental and applied research evidence as to the relative effect of directed discovery, in situations providing numerous problem solving opportunities, upon initial learning, retention, and transfer of micrometer measurement principles and skills as compared with traditional, direct and detailed instruction in these situations, with three levels of intelligence. (43:459)

Rowlett used orthographic projection principles and skills with the same purpose in mind, and Moss made use of letterpress imposition. (45:4589-4590; 42:2992)

All three studies found teacher-directed student discovery and traditional detailed teacher instruction to be equally effective in regard to initial student learning. Ray and Moss found that after one week student retention was equally effective. After a similar period of time amounting to twelve days, Rowlett found retention to be greater among students who had learned through teacher-directed discovery. Retention six weeks later, transfer one week later (Rowlett used a twelve day interval instead), and transfer six weeks later were all found by Ray and Rowlett to be greater in students who had learned through directed discovery. Moss found no difference in any category. This research was significant because it showed that a teaching approach related to problem solving was at least as effective in all tested respects and probably more effective in retention and transfer.

Robert Tinkham wrote in 1952 that "few of the teachers [he] questioned had sensed the potentialities inherent in teaching modern design--the rich possibilities in problem solving, critical thinking, and creative expression." (60:196) After a study of philosophy and practices in modern education, modern design, and industrial arts, he developed a suggested method for teaching design in the school shop.

> For maximum pupil growth--creatively, intellectually and emotionally--actual experiences in project designing should be encouraged. The method presented in the study capitalizes on the pupil's ability to advance beyond the rote-learning level. It places a premium on his skill in analyzing the function of an object, on his ability to do research suitable to his level and on his improvement in thinking through a design problem starting with the need for the object and finishing with the completed project. (60:196)

There are now at least five dissertations relating to problem solving as a concern of industrial arts instruction in process of preparation. (48:3-5) They deal with methods of instruction, and with designing and creativity.

<u>Summary of Decade 1951-1960</u>

In the years since 1930, there has been an increasing concern among educators in the field of industrial arts about relating problem solving to the foundations of education. In the decade 1951-1960, there has been a much needed emphasis placed on philosophical and sociological foundations. Certainly, the literature in the area shows that there has been, during the past decade, greater development of problem solving as an objective of industrial arts instruction than in either of the previous decades covered in this review. The roots of this objective can be traced back to the needs of democratic society and to needs of individuals attempting to meet the problems of living.

In problem solving as a method of learning, there also has been more consideration shown in the literature of the Fifties than in previous decades. From psychology, learning theory has been brought to bear on problem-solving method as means for improving problem-solving ability. The opinion of many of the persons who have been writing in the area of industrial arts in the Fifties has been that achievement in student problem solving is dependent upon the teaching methods used. It appears to be evident that there has been in the past ten years, a growing preference for problem-solving method as the best one to achieve the objective of the improvement of problem-solving ability. Problem-solving method has even been favored by some for the teaching of skills and information.

There was noted a difference of opinion regarding the amount of basic skill and knowledge students need in industrial arts classes before they can be given problem-solving experiences in the form of design problems. According to one source, some background in fundamentals seemed necessary; according to another source, students can begin to design with their first experience in industrial arts.

A variety of student activities were identified and developed as having potential for developing problem-solving ability. Included were research and experimentation, design problems, individual projects, group projects, and problems in student government. Interest seemed to be most highly exhibited in the areas of design, design problems, and individual projects.

The first significant research related principally to problem solving was done in this decade. There was more concern with methods and techniques for guiding teachers in improving student problem-solving abilities. Some studies of the Fifties touched on problem solving as related to objectives, methods, and student activities. Only a beginning had been made, however; miles of territory are yet unmapped. It seems interesting that a large amount of the research in the past several years has been done by doctoral candidates.

<u>Overview of Industrial Arts Concern for Problem Solving Based Upon Survey of the Literature--1930-1960</u>

There is clear indication of a recent surge of interest in problem solving. In the research for this review eighteen sources published in the Thirties were found to be pertinent. Nine were found in the Forties, and forty-nine in the Fifties. Pertinent sources of the past decade are almost twice as numerous as those of the previous two decades combined. Of the seventy-six sources found (all were not included in this report), approximately one-half were dated in the last four years (1957-1960).

Increasingly evident is the concern for relating problem solving to the sociological, psychological, and philosophical foundations of education. Attempts to base teaching procedure on the current psychology of learning of each decade were noted. Relation of problem-solving method to sociological and philosophical foundations of education became more apparent during the past decade.

Industrial arts leaders appear to show a growing preference for and concern with problem solving as an objective and as a method of instruction. The interest of secondary school teachers, however, apparently has been much less, as indicated by their ranking of Warrick's objectives shortly after World War II, and by Burns' study in the early Fifties. Problem solving was found to occupy a secondary position in most listings of industrial arts objectives.

Although beginnings have been made toward a comprehensive definition of problem-solving abilities, in terms of expected behavioral outcomes that would be typical in the area of industrial arts, much remains to be done.

There is general agreement among those who discussed the subject that improvement of problem-solving abilities should be the objective of teaching rather than a concomitant outcome of other teaching objectives.

There was little disagreement among the sources that

problem solving is best improved through continued experience in solving realistic problems. There was distinct disagreement, however, about when students should undertake the solving of various kinds of problems.

In addition, the problem-solving method was considered an effective method for teaching knowledges, attitudes, and skills associated with other teaching objectives of industrial arts. Research by industrial arts persons indicated that a modified problem method was more effective than traditional direct-telling methods in teaching certain common concepts and skills of industrial arts.

A variety of activities or learning vehicles were identified and developed to improve student problem-solving abilities.

Some sources considered designing and problem solving to be practically synonymous processes. Some considered the project method similar to problem-solving method. Caution was advised regarding emphasis on individual project design as the answer to providing experience in problem solving.

Research on problem solving and related topics is a comparatively recent phenomenon in industrial arts. Some worthwhile contributions were made and others apparently are in process.

Bibliography

1. Anderson, Arthur D., and Ferns, George W. "Students Can Now Develop Own Designs," School Shop, XVIII (March, 1959).

2. Anderson, Herbert A. "Designing is Problem Solving," Industrial Arts and Vocational Education, XLVI (September, 1957).

3. ________, and Olsen, K. T. "How Appropriate Is a Project?" Industrial Arts and Vocational Education, XLII (January, 1953).

4. Baird, Ronald J. "The Application of John Dewey's Philosophy to Industrial Arts Teacher Education." Unpublished Ed. D. dissertation, College of Education, Michigan State University, 1960.

5. Bawden, William T. "Review of Industrial Education for the Biennium," Industrial Education, XL (January, 1938).

6. Bennett, Charles A. "A Creative Method Project," Industrial Education, XL (May, 1938).

7. Blosser, Charles. "Bibliography of Publications in Professional Subjects for Industrial Arts and Vocational Education." Unpublished bibliography, College of Education, Michigan State University, 1960.

8. Bro, Ronald. "Ways to Teach Industrial Arts Design," Industrial Arts and Vocational Education, XLVIII (December, 1959).

9. Burns, Clyde E. "A Study of the Use of the Problem Solving Approach in Industrial Arts Programs in Florida Secondary Schools." Unpublished Ed. D. dissertation, School of Education, Florida State University, 1952, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XII (1952).

10. ________. "Think a Problem Through," School Shop, XV (December, 1953).

11. Christy, Elmer W. "The Place of Industrial Arts in the Educational Program of Senior High Schools," Industrial Education, XLI (January, 1939).

12. Duffy, Joseph. "A Democratic Pupil Personnel Plan," Industrial Arts and Vocational Education, XLIV (November, 1955).

13. Earl, Arthur W. Experiments With Materials and Products of Industry. Bloomington, Ill.: McKnight and McKnight Publishing Co., 1960.

14. ________. "How to Use a Research-Experimentation Approach," Industrial Arts and Vocational Education, IL (November, 1960).

15. Ericson, Emanuel E. Teaching the Industrial Arts. Peoria, Ill.: The Manual Arts Press, 1946.

16. Ferns, George W., and Anderson, Arthur D. "Problem Solving and Designing," School Shop, XIX (May, 1960).

17. Fox, Jesse G. "Industrial Arts Methods in Junior High School," Industrial Arts and Vocational Education, XXVIII (May, 1939).

18. Friese, John F. Course Planning in Industrial Education. Peoria, Ill.: The Manual Arts Press, 1946.

19. ________. "Philosophy of Industrial Arts for American Education," Industrial Arts and Vocational Education, XXIX (January, 1940).

20. French, Will, and Others. Behavioral Goals of General Education in High School. New York: Russell Sage Foundation, 1957.

21. Fryklund, Vern C. "Problem-solving Attitudes," Industrial Education, XXXIX (November, 1937).

22. ________. "The Place of Reasoning in the School Shop," Industrial Education, XXXII (January, 1931).

23. Fuzak, John A. "Analysis of Developments to Determine Implications for Industrial Arts," Industrial Arts Teacher, XVII (November-December, 1957).

24. ________. "Concepts of Professional Education," Problems and Issues in Industrial Arts Teacher Education, Fifth Yearbook of the American Council on Industrial Arts Teacher Education. Bloomington, Ill.: McKnight and McKnight Publishing Co., 1956.

25. ________. "Reflective Thinking as an Aim in Industrial Arts," Education, LXV (June, 1945).

26. Grinstead, N. B. "The Learning Situation Afforded by Industrial Arts," Industrial Education, XXXI (February, 1929).

27. Harrison, Oval S. "On Effective I-A Teaching," Industrial Arts and Vocational Education, IL (January, 1960).

28. Hess, Louis A. "A Teaching Procedure that Stimulates Creative Thinking," Industrial Education, XL (January, 1938).

29. Hostetler, Ivan, and Others. "The Future Role of the Project in Industrial Arts," Industrial Arts and Vocational Education, IL (October, 1960).

30. Hunter, William L. "Manual Arts in the Junior High School," Industrial Education, XXXI (July, 1929).

31. Jagosz, Edward, and Others. "A Bibliography of Microfilmed Dissertations in Industrial Education, 1939-1959," Department of Industrial Education, Wayne State University, Detroit, 1959.

32. Karnes, Raymond M. "Improving Industrial Arts Education," Industrial Arts Teacher, XIX (May-June, 1960).

33. Keener, Clyde. "A Study of the General Educational Contribution of Industrial Arts." Unpublished Ed. D. dissertation, University of California, Los Angeles, 1959.

34. Lahti, Aarre K. "Design for Industrial Arts," Industrial Arts Teacher, XIX (March-April, 1960).

35. Lux, Donald G. "Teach Them How to Solve Problems," Industrial Arts and Vocational Education, XLVIII (May, 1959).

36. ________. "The Role of Art in Industrial Arts," Industrial Arts and Vocational Education, XLVII (May, 1958).

37. Maley, Donald. "Research and Experimentation in the Junior High School," Industrial Arts Teacher, XVIII (March-April, 1959).

38. Mays, Arthur B. Essentials of Industrial Education. New York: McGraw-Hill Book Co., 1952.

39. ________. "Neglected Values in Industrial Arts," Industrial Education, XXXIX (September, 1937).

40. Micheels, William J. "Industrial Arts Teacher Education in 1970," Industrial Arts and Vocational Education, XLVII (February, 1958).

41. ________, and Sommers, Wesley S. The Minnesota Plan for Industrial Arts Teacher Education. Bloomington, Ill.: McKnight and McKnight Publishing Co., 1958.

42. Moss, Jerome. "An Experimental Study of the Relative Effectiveness of the Direct-Detailed and the Directed Discovery Methods of Teaching Letterpress Imposition." Unpublished Ed. D. dissertation, Department of Industrial Education, University of Illinois, 1960, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XXI (1961).

43. Ray, Willis E. "An Experimental Comparison of Direct and Detailed and Directed Discovery Methods of Teaching Micrometer Principles and Skills." Unpublished Ed. D. dissertation, Department of Industrial Education, University of Illinois, 1957, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XVIII (1957).

44. Rowlett, John D. "A Year in a Maze," School Shop, XVIII (May, 1959).

45. ________. "An Experimental Comparison of Direct-Detailed and Directed Discovery Methods of Teaching Orthographic Projection Principles and Skills." Unpublished Ed. D. dissertation, Department of Industrial Education, University of Illinois, 1960, listed in Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform, XX (1960).

46. Selvidge, R. W. "The Teacher's Objectives." In Industrial Arts in Modern Education: Published in Celebration of the Twenty-fifth Anniversary of the Manual Arts Conference of the Mississippi Valley. Peoria, Ill.: The Manual Arts Press, 1934.

47. Siepert, A. F. "Methods of Teaching and Organization of Subject Matter." In Industrial Arts in Modern Education: Published in Celebration of the Twenty-fifth Anniversary of the Manual Arts Conference of the Mississippi Valley. Peoria, Ill.: The Manual Arts Press, 1934.

48. Silvius, G. Harold, and Wenrich, Ralph C. Recent Research in Industrial Arts. A Report to the Mississippi Valley Industrial Arts Conference, Chicago, November, 1960.

49. Smith, Homer J. "Industrial Arts, a Vital Service," Industrial Education, XXXIX (March, 1937).

50. Sommers, Wesley S. "Design in Your Shop Program," School Shop, XVII (February, 1958).

51. ________. "Design or Art," School Shop, XVII (November, 1957).

52. ________. "Integrating Design with Laboratory Classes," Industrial Arts Teacher, XVIII (January-February, 1959).

53. Soules, Ray L. "Values Inherent in Industrial Arts Education," Industrial Education, XLI (September, 1939).

54. Starrak, J. A. "Some Important Values to be Derived from Industrial Arts When Properly Taught," Industrial Education, XXXVII (January, 1935).

55. Stone, William H. "Recent History and Trends." In Industrial Arts in Modern Education: Published in Celebration of the Twenty-fifth Anniversary of the Manual Arts Conference of the Mississippi Valley. Peoria, Ill.: The Manual Arts Press, 1934.

56. Street, Calvin M. "Concepts of General Education," Problems and Issues in Industrial Arts Teacher Education. Fifth Yearbook of the American Council on Industrial Arts Teacher Education. Bloomington, Ill.: McKnight and McKnight Publishing Co., 1956.

57. Strichler, Jerry. "Methods of the Industrial Designer," Industrial Arts and Vocational Education, XLVIII (December, 1959).

58. Struck, Theodore F. Creative Teaching. New York: John Wiley and Sons, 1938.

59. Swanson, Robert S. "Psychology of Learning and the Teaching of Industrial Arts," Industrial Arts and Vocational Education, XLV (October, 1956).

60. Tinkham, Robert A. "Design in Industrial Arts: A Study of Creative Modern Design as it Relates to the Teaching of Industrial Arts." Unpublished Ph. D. dissertation, Department of Industrial Education, University of Minnesota, 1952, listed in _Dissertation Abstracts, a Guide to Dissertations and Monographs Available in Microform_, XIII (1953).

61. Van Tassel, Raymond (ed.). _Research in Industrial Arts Education._ Ninth Yearbook of the American Council on Industrial Arts Teacher Education. Bloomington, Ill.: McKnight and McKnight Publishing Co., 1960.

62. Warrick, Glen. "Industrial Arts Objectives," _Industrial Arts and Vocational Education_, XXXVI (September, 1947).

63. Whitesel, John A. "Industrial Arts in the Modern Senior High School," _Industrial Arts and Vocational Education_, XXXV (September, 1946).

64. ________. "The Derivation of Goals and Purposes of Instruction," _Problems and Issues in Industrial Arts Teacher Education._ Fifth Yearbook of the American Council of Industrial Arts Teacher Education. Bloomington, Ill.: McKnight and McKnight Publishing Co., 1956.

65. Wilber, Gordon O. _Industrial Arts in General Education._ Scranton, Pa.: International Textbook Company, 1948.

66. Wright, Lawrence S. "Drawing, Problem Solving, and Industry," _Industrial Arts and Vocational Education_, XLV (October, 1956).

67. ________. _Selected Industrial Arts Research Completed in 1960._ A report to National Association of Industrial Teacher Education, American Vocational Association Convention, Los Angeles, December, 1960.

68. Young, Talmage B. "The Group Project as a Beginning I. A. Experience," _Industrial Arts and Vocational Education_, IL (October, 1960).

APPENDIX B

PROBLEM SOLVING OBJECTIVE DEFINED BEHAVIORALLY

The Russell Sage Foundation study of behavioral goals for secondary school general education gives the following behavioral description of problem solving abilities:

1.13 Becoming Sensitive to, and Competent in, the Use of Logical Thinking and Problem-Solving Processes.

1.131 Tends to make an objective approach to a problem and attempts to define it clearly.

Illustrative Behaviors

(a) Respects and uses with understanding the scientific method for discovering solutions to problems.*

(b) Listens to conversations and speeches effectively and understands and organizes for his own use the points made by others.

(c) Seeks for answers, asks questions, looks for causes.*

(d) Recognizes and states or defines a problem carefully and sees the necessity of doing this.*

(e) Analyzes a problem and can follow the recognized steps involved in scientific thinking.*

1.132 Seeks pertinent information and organizes and evaluates data.

Illustrative Behaviors

(a) Seeks facts, collects and evaluates information, and gathers evidence on all sides of problems which he must solve.*

(b) Shows skill in collecting data from a variety of sources and in organizing those needed to solve his problems.*

(c) Verifies data in an effort to distinguish between fact and opinion.*

(d) Evaluates evidence or authority. Recognizes stereotypes and cliches.*
(e) Recognizes bias and emotional factors in a presentation and in his own thinking.

1.133 Recognizes logical and illogical thinking in his efforts to reach reasonable conclusions.

Illustrative Behaviors

(a) Is gaining in ability to identify glaring flaws in purportedly logical discourse (e.g., circularity, post hoc attributions of cause, "undistributed middle") not by any particular labels but simply as unwarranted claims of proof.*
(b) Seeks to free himself from fears due to ignorance and superstitions.*
(c) Recognizes the unsoundness of drawing generalizations from insufficient evidence.*
(d) Applies generalizations to new situations.*
(e) Demonstrates some ability to reason from cause to effect.*
(f) Tries to draw logical conclusions.*
(g) Seeks to identify unstated assumptions which are necessary to a line of argument.*
(h) Recognizes that both defensible and indefensible techniques are used in attempts to influence thought and behavior; propaganda, rumors, sterotypes, emotional appeals, etc.*
(i) Recognizes that accuracy and integrity are essential to critical thinking, and holds himself to the highest standards in both respects.*
(j) Views understandingly and objectively the role and significance of persuasion in our society from the standpoint of an interested consumer.[1]

*Outcomes that were evaluated by 90 per cent of the reviewers as of "high" importance are indicated by an asterisk.

---

[1]Will French, and Others, Behavioral Goals of General Education in High School (New York: Russell Sage Foundation, 1957), pp. 100-102.

APPENDIX C

ATTITUDES FAVORABLE TO PROBLEM SOLVING

Dressel and Mayhew described attitudes toward rational and scientific thought processes as:

1. Systematic reflection accepted as preferable to snap judgment.
2. Disposition to regard most problems as problems that can be solved, but that some are insoluble.
3. Recognition of the limitations of knowledge and appreciation of the functions of faith.
4. Recognition that learning is a continuous life-long process.
5. Respect for expert judgments combined with the desire to validate these judgments against experience.
6. Willingness to reserve judgment but also to act when action is required.
7. Responsibility of the student to take initiative in the learning process.
8. Making practical applications of what is learned.
9. Intellectual curiosity and honesty.
10. Faith in the possibility of communication with others and a recognition of the limitations of language.
11. Desire to relate all of knowledge into a systematic and coherent pattern as over against compartmentalizing knowledge in discrete areas.
12. Disposition to regard the solution of problems as relative to the particular cultural context in which the problems arise rather than constituting a solution which is of absolute validity for all cultures and epochs.[1]

---

[1]American Council on Education, General Education: Explorations in Evaluation; the Final Report. A Cooperative Study of Evaluation in General Education directed by Paul L. Dressel, assisted by Lewis B. Mayhew (Washington: American Council on Education, 1954), pp. 214-215.