THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

A CONCEPTUAL APPROACH FOR BETTER UNDERSTANDING OF INDUSTRIAL SHOP WORK IN ONE-TEACHER INDUSTRIAL ARTS SHOPS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF EDUCATION

BY

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Norman, Oklahoma

1958

A CONCEPTUAL APPROACH FOR BETTER UNDERSTANDING
OF INDUSTRIAL SHOP WORK IN ONE-TEACHER
INDUSTRIAL ARTS SHOPS

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ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to the chairmen of his committee and advisors, Dr. Chester Williams and Dr. Robert Hardin, for their invaluable assistance and encouragement in the development of this study. Special thanks are extended to the high school teachers of Iowa who gave their time and ideas unsparingly and to the Iowa College teacher-educators who gave the benefits of their experience.

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CHAPTER I

INTRODUCTION

In the history of education there are many instances in which educators have sought to make schools more realistic in their services to society. Present day attempts to achieve this goal are merely steps in an evolutionary process. Some activities of the school are characterized by student contact with concrete items and by manipulative activity. Industrial arts exemplifies such activities.

The ability to perform inductive thinking seems to have been a highly valued objective through the years. Concepts are needed to reason effectively, but in the busy, highly manipulative, atmosphere of the industrial arts shop, conceptual development may not be given the amount of attention necessary to make best use of the limited shop time usually provided. Concepts may not be recognized, may be taken for granted, or actually ignored. If teachers can be made aware of the fact that a number of capable experienced teachers think that conceptual development in industrial arts is important, and that concepts of industry can be identified and implemented, then the valued ability to "reason" will find specific encouragement as industrial arts activities are modified to achieve this end.

The essence of industrial arts shop work is manipulation and physical activity. Industrial arts teachers are aware of the danger that shop work can become "just an activity," making no significant contribution to the effective development of the students.

The industrial arts teacher, particularly the beginning teacher, requires a starting point upon which to develop his own industrial arts shop according to his particular teaching circumstances. It is believed that to find representative concepts of industry and by example to show that such concepts may be helpful in teaching will contribute to more significant industrial arts shop work. The teacher will be helped to recognize other concepts appropriate to his shop situation and to arrange activities which will provide perceptions and experiences which the student can organize into useful concepts. More specifically, it has been noted in industrial arts shops that students can go through a series of manipulative activities and acquire certain amounts of information. In spite of these facts they may not be able to relate these activities effectively to other problems. Perhaps they have perceived certain facts but not developed concepts helpful in interrelating their knowledge to industry or even to other areas of industrial arts.

If our schools are to acquaint the students with phases of industry where repetition and imitation are not of primary importance, the ability to integrate facts into concepts and these into varied patterns is necessary. As far as industrial processes are concerned, it would seem a duty of industrial arts to help the pupils understand many phases of industry at the conceptual level. By way of example, a new phase of industry, automation, is coming into common use. Its effect upon the labor force is at least two-fold. First, numbers of machine-operators may be displaced temporarily, until absorbed again in the expansion of production. Secondly, automatic machines need to be maintained and adjusted. Whereas this may not necessarily be a job for an engineer, it will require increased numbers of technicians with considerable understanding of the machines, what they do, and how they work. Men will be in demand who have broad concepts of the whole of the processes conducted by the machines and of the means by which the machines accomplish these processes. Only such concepts will enable a technician to keep the machines running or find the source of trouble when they stop. Thus it seems that the concepts involved in industrial processes will be increasingly more important than the ability to do repetitive manipulations.

Help, to be most useful to the teacher, must suggest activity, be specific, and be adapted to a particular school situation. The degree to which the industrial arts shop circumstances can be altered is deeply enmeshed with the total problems of the school, i.e., space, budget, other responsibilities, etc. In the face of such problems, extremes may be resorted to, especially by beginning teachers. Shop activity ranges from out-and-out imitative activity to duplications of academic classroom situations. Objectives may become lost and the effect quite superficial in situations of this type. The teacher needs some basic guide to aid in the selection of areas for the shop, of activities to be done, and of method of presentation.

In Iowa there are many schools of limited size in which one teacher is charged with the responsibility of operating an industrial arts shop to the end that the pupils will have an opportunity, among other things, to discover aptitudes for and interest in activities representative to a degree of the productive activities of industry. It is true that there are quite a number of larger schools where several teachers work toward this end and even a larger number of smaller schools with no program of industrial arts at all. From a quantitative standpoint and the viewpoint of guidance-need, the man in the one-teacher industrial arts shop seems to be the one in most need of help. Because of the foregoing statements this study emphasizes the one-teacher shop.

Statement of the Problem

The purposes of this thesis are (1) to determine the possibilities of a conceptual approach to secondary school industrial arts teaching in the one-teacher diversified industrial arts shops of Iowa, (2) to determine the attitude toward such an approach on the part of selected teachers in such industrial arts shops, and (3) to discover, in the selected areas of industrial arts woodwork, drawing, metalwork, and electricity, items of information which will contribute to the forming of concepts related to industry.

Beginning teachers and others are concerned about the many ideas existing in regard to the objectives of industrial arts. They may find it easier to teach a number of "how to do it" activities than to organize activities to provide concepts of utility to the program of general education and hence of use to all of the students whatever their station in later life, being related to industrial arts shop work or not. Although gaining an understanding of industry is but one of the aims of industrial arts, it is one aim which the industrial arts shops seem especially able to implement.

Importance of the Study

Divergence of opinion among teachers of industrial arts in Iowa with reference to what should constitute the activities of the one-teacher industrial arts shop clearly indicates an area in need of research.

The writer, as a member of the faculty of the Iowa State Teachers College, has spent thirteen months visiting schools in Iowa as an industrial arts consultant. This experience served as the basis for the following observations:

1. There is a need for a realistic approach to industrial arts teaching in the industrial arts shops of Iowa secondary schools.

2. The success of a change in industrial arts teaching will hinge upon acceptance by the teachers and upon their contributions to such innovations.

3. Teachers of industrial arts in Iowa are continually re-examining their industrial arts activities in the light of significant contributions to general education.

There is little disagreement among the industrial arts teachers as to the importance of industrial arts, or as to the worthy character of the many objectives which have been established for industrial arts. The problem hinges upon making the most effective and the most significant use of the school time allotted for industrial arts.

Industrial Areas Selected for Study

In the selection of phases of industry to be emphasized in assisting the pupil to understand industry, some consideration should be given, certainly, to the numbers employed in various industries. From a quantitative point of view we should probably acquaint our pupils with skilled fields in some order of the numerical importance of the field. Table 1 lists the major industries of the United States, the numbers employed, and the value of the product.

TABLE 1

INDUSTRIES IN THE UNITED STATES*

Number of Employees	Groupings	Value of Product in Thousands of Dollars
1,911,706	Transportation equipment	$ 14,534,323
1,691,235	Machinery (except electrical)	13,380,729
1,455,110	Foods and kindred products	11,937,510
1,287,765	Primary metal industries	11,003,954
1,227,161	Apparel and related products	5,414,627
1,158,471	Textiles, mill products	5,411,769
1,117,600	Fabricated metal products	8,143,660
1,095,852	Electrical machinery	7,876,186
843,544	Miscellaneous industries	5,271,811
768,425	Chemicals and allied products	9,320,348
760,332	Printing and publishing industries	5,916,432
719,900	Lumber and products (except furniture)	3,500,524
533,312	Paper and allied products	4,463,237
506,439	Stone, clay and glass products	3,752,912
375,364	Leather and leather products	1,711,066
360,842	Furniture and fixtures	2,046,805
285,469	Instruments and related products	2,169,354
269,780	Rubber products	2,021,443
229,294	Petroleum and coal products	2,795,373
95,442	Tobacco manufacturers	987,073
17,093,004		$121,659,136

*U. S. Bureau of the Census, Statistical Abstracts of the United States (Washington, D. C.: U. S. Government Printing Office, 1955), p. 807.

Table 2 deals with people who are in the crafts or skilled trades and with foremen who should also possess such skills as well as the ability to lead. The areas of the industrial arts shop of wood, metal, drawing, and electricity which have been selected for more detailed study are seen to rank high in both tables, in that they have implications for several of the industries listed.

TABLE 2

NUMBERS OF SKILLED PERSONNEL IN INDUSTRIES*

United States Industries Involving Skilled Personnel	Number Employed
Crafts, foremen, and kindred workers	
Cabinet makers	76,421
Carpenters	985,443
Electricians	324,046
Radio and Television	78,259
Linemen (telephone, etc.)	215,948
Auto Mechanics	677,569
Machinists	533,726
Sheet Metal	129,639
Professional, technical, and kindred workers	
Architects	25,000
Draftsmen	124,749
Electrical Engineers	108,137
Photographers	54,724
Radio Operators	16,421

*U. S. Bureau of the Census, Statistical Abstracts of the United States (Washington, D. C.: U. S. Government Printing Office, 1953), p. 788. (Data are from Table 124, p. 1-261 and p. 1-263.)

Table 3 compiles figures from Table 2 on the employment in industries related to electricity. This is an area of relatively recent industrial arts development and illustrates the importance of following the changes of our industrial life.

TABLE 3

PERSONNEL IN INDUSTRIES RELATED TO ELECTRICITY

Industries Related to Electricity	Number Employed
Electricians	324,046
Radio and TV	78,259
Linemen	215,948
Radio Operators	16,421
Electrical Engineers	108,137
	742,811

Experienced industrial arts teachers are aware of the existence of other objectives of the industrial arts program in addition to assisting the pupil to gain an understanding of industry. They are aware also that certain industrial arts areas such as woodwork seem uniquely adapted to the school situation and to the backgrounds of many teachers. However, the numbers of our citizens gaining a livelihood in each of the industries is also a guide as to what should be taught as the school situation permits. Teachers of industrial arts should be constantly aware of the changing industrial picture and consider modifying their curricula in the light of such changes.

An investigation, then, is clearly in order, one which, in part, may discover the willingness of teachers to accept a different approach to their selection of activities and consequently offer the interested teacher some specific help in making a marked change in instructional approaches in the areas of (1) woodwork, (2) metal work, (3) drawing, and (4) electricity.

It seems reasonable to think that if teachers in such one-teacher shops, or the young teacher uncertain what to include in his program, could be interested in the desirability of developing concepts regarding industrial processes, one sound basis for selection of instructional material would be present. Of course, since there are other objectives of a complete industrial arts program, all activities cannot be selected to develop concepts of industrial processes, but these can become a unifying thread through all phases of the activities of the one-teacher shop. Too often the program in a one-teacher shop consists of unrelated activities selected from traditional industrial arts areas. The students have a smattering of many things without perceiving much continuity nor many relationships in what they have done because the teacher has not selected the activities to develop such understandings. It would seem that if a teacher could be made aware of the concepts that might be developed in an industrial arts program and would select activities with the aim of developing such concepts, unity would appear in the program. Developmental sequences of activities that would enable the students to see relationships and develop concepts would be possible.

Even though this seems logical to one working with curriculum planning, it is necessary to determine the attitude of the teachers toward such an approach. If a large percentage of the teachers fail to understand the approach of developing concepts or are unreceptive to it, or can see no gain in modifying their programs to include it, curriculum plans based on this approach will find little or no use in the industrial arts curriculum. Improvement can occur when ideas are accepted by the teachers and put into effect in the industrial arts shops.

If a teacher is receptive to a different approach to his teaching, the most important block to making a change is uncertainty as to how to accomplish the desired ends. For the man in the one-teacher shop situation there is now seldom time available to do the necessary reading, thinking, or planning that a major change in teaching approach involves. However, if he can find suggestions that he can adopt or adapt directly into his work, the change will be greatly accelerated. Having made the change, the teacher often is stimulated to produce ideas of his own to make further modifications.

The determination of concepts that can be developed in a one-teacher industrial arts shop seems to be in its early stages. There are, however, several ways to attempt to identify the concepts. Teachers themselves and men in industry can contribute on the basis of what they know of students and of industry. Another good starting point is the literature written for the technicians or workers within an industry. This literature, if it has more than recipe-type directions of how to do something, includes concepts that the authors deem valuable for the worker in a particular area. These same concepts, therefore, would seem to have value in helping the industrial arts student develop an understanding of industry and industrial processes.

Limitations of the Study

Preliminary consideration of the conceptual approach to industrial arts teaching made it clear that the subjective and philosophical nature of concept formation would place a number of practical limitations upon the procedure for conducting the study.

One important limitation was the amount of time the participants could reasonably be expected to contribute to the study. Unlike data gained by counting concrete items such as tools and equipment, or data obtained in areas which have received much publicity and discussion, data regarding concept formation in industrial arts obviously require face to face discussion at least for the greater part of a school day, before a frame of reference and a rapport can be established in which significant data can be obtained.

A second limitation was the geographic distribution of the participants who could be contacted on a personal interview basis.

A third limitation was the need that the participants have had experience in teaching in the one-teacher industrial arts shop on the secondary level and that there be evidence available that they are interested in improving their teaching procedures.

As a result of these limitations, the following guides for the study seemed to be appropriate:

1. Obtain opinionnaire data on a personal interview basis, allowing one full school day for discussion.

2. Limit the participants to those teaching in the State of Iowa.

3. Limit the scope of the study to the one-teacher industrial arts shop which is the dominant type in Iowa.

4. Limit the secondary school teacher participants to those who have had experience in teaching the one-teacher industrial arts shop and who have utilized the consultative services of the Field Services Division of the Iowa State Teachers College.

5. Limit the nature and scope of the data to that feasible of attainment yet providing ample depth and penetration during the time limits of a single school day. It was

apparent that a lengthy discussion of the conceptual approach would need to precede any attempts to gather data.

6. Include as participants college teacher-educators in the only institutions in Iowa offering major preparation in industrial arts. These were selected because of their broad experience in Iowa and their influence upon industrial arts teachers and industrial arts teaching.

7. Limit the industrial arts areas to four: those representative areas of woodwork, drawing, metal work, and electricity.

Methods of Research

The philosophical character of concept and concept formation largely determined the method of research. The following procedures held prospects of achieving useful data.

Determining the Nature of Concepts

Preliminary discussions with teachers and colleagues revealed a lack of unanimity regarding the nature of concepts. Previous literature regarding concepts was studied to discover the viewpoints of modern leaders in education and psychology as to the nature of concepts. Considerable agreement was discovered among these individuals.

Identifying a Typical Concept in Industrial Arts

Preliminary discussions with teachers and colleagues showed the impracticability at this time of requesting the participants in the study to do extensive research regarding concepts and concept formation in industrial arts. Hence it became essential to identify and describe a concept in industrial arts which would involve an activity with which all the participants would be familiar. The Concept of the Cutting Edge proved effective for this explanatory purpose.

Surveying the Literature of Industrial Arts to Discover Concepts in the Four Selected Areas of Woodwork, Drawing, Metalwork, and Electricity

It was believed that this thesis could be made more effective if it could be demonstrated that concepts in these four areas can be identified in terms of the frame of reference established for identifying concepts.

Determining the Attitude of Secondary School Industrial Arts Teachers in Iowa Toward a Concept Approach to Industrial Arts Teaching

Personal visits, informal discussions, and structured interviews involving a formal opinionnaire were utilized for this purpose. The opinionnaire was devised on the basis of the survey of the literature and the previous experiences of the writer during fifteen months as a field consultant in industrial arts in Iowa. Preliminary discussions with teachers in the field indicated that the unfamiliarity with concepts and concept formation would require that the opinionnaire be discussed personally and at length before a basis for answers and comments could be established.

Determining the Attitude of College Teacher-Educators in Iowa Toward a Concept Approach to Industrial Arts Teaching

Personal visits, informal discussions, and structured interviews involving the opinionnaire previously mentioned were utilized for this purpose. The educators who were included represented the only institutions in Iowa offering major preparation in industrial arts and they greatly influence industrial arts teaching in Iowa.

Tabulating and Interpreting the Data Obtained by Means of the Opinionnaire and the Discussions with Teachers

It was believed that the amount of agreement or disagreement disclosed by the opinionnaire would tend to indicate the degree of acceptance the conceptual approach to industrial arts teaching would encounter in Iowa. Providing the teachers with a chance to express themselves informally was intended to produce helpful information at the "grassroots" level in practical teaching situations.

Definition of Terms

Industrial Arts

Bonser and Mossman say that industrial arts is a "study of the changes made by man in the forms of materials to increase their values, and the problems of life related to these changes."[1]

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[1]Frederick G. Bonser and Lois C. Mossman, Industrial Arts for Elementary Schools (New York: The Macmillan Company, 1923), p. 5.

Fales defines industrial arts as "the broad study of the materials, organization, tools, processes, products, jobs, and human problems of industry."[1]

Wilber defines industrial arts as "those phases of general education which deal with industry--its organization, materials, occupations, processes, and products--and the problems resulting from the industrial and technological nature of society."[2]

A particularly descriptive definition of industrial arts was accepted by the Oklahoma State Department of Education:

> Industrial arts is a group of school subjects that contribute to the attainment of the goal of general education by furnishing guided experiences in the use of tools, materials and machines, and insights into those phases of industry that have become an important part of our social culture.[3]

Industrial arts is, then, generally regarded as a phase of general education. A primary aim of industrial arts shop work is to assist students to understand better the shop activities of industry. Industrial arts is, in part, an exploratory prelude to the selection of a vocation

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[1]Roy G. Fales, Industrial Arts, Tentative Syllabus in Comprehensive General Shop (Albany, N. Y.: University of the State of New York, 1940), p. 3.

[2]Gordon O. Wilber, Industrial Arts in General Education (Scranton, Pa.: International Textbook Company, 1948), p. 2.

[3]Oklahoma State Department of Education, "Industrial Arts in Oklahoma," Bulletin No. 105, 1951 (Oklahoma City, 1951), p. 1.

for which the pupil may later seek intensive preparation in order to gain economic competency. Industrial arts, therefore, is general in nature and is thus differentiated from vocational industrial education which the student may later enter for intensive, specific, and terminal training aimed at industrial competency.

Percepts and Concepts

In view of the wide range of connotations encountered among teachers in the field, it is necessary to seek agreement on the definition of the terms percept and concept.

Definitions in Webster's New International Dictionary have been selected as an acceptable authoritative source:

> Perception 1. Any act or process of knowing objects, facts, or truths, whether by sense experience or by thought; awareness of objects; consciousness. This original broad meaning is now rare in psychology. 2. Reference of sensation to an external object; a A direct acquaintance with anything through the senses. b The power or function of perceiving by the senses. c The process of perceiving. d The result of this process; what is known about an object by seeing or hearing it, etc.; a percept.[1]

Webster is again helpful in distinguishing concept from percept:

> A concept . . . an idea, as distinguished from a percept; esp., as orig., an idea representing the meaning of a universal term and comprehending the essential attributes of a class or logical species; now, chiefly, an idea that includes all that is characteristically associated with, or suggested by, a term.

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[1]W. A. Neilson, et al., Webster's New International Directory of the English Language (Springfield, Mass.: G. C. Merriam Co., 1952), p. 1816.

> Conception is . . . 3. The power to function, or process of forming ideas, esp. abstract universal ideas, or of grasping the meaning of words and other symbols. . . . 4. c The abstract, intellectual, or universal element in cognition, as contrasted with the apprehension of concrete particulars in sense perception.[1]

The Conceptual Approach to Industrial Arts Teaching

This approach involves primarily the arranging of an industrial arts shop situation so that the activities will help the student gain insights as to how fundamental industrial principles are utilized.

Organization

Chapter I is devoted to a description of the procedure by which the problem was approached. Chapter II deals with related literature. Chapter III is concerned with the method of procedure employed in determining (1) the attitude of industrial arts teachers in Iowa toward a concept approach to teaching and (2) investigating representative concepts for the selected areas. Chapter III also describes the participants' reactions to the structured interview and opinionnaire and presents an evaluation of the items used in the opinionnaire. Chapter IV deals with the concept of the cutting edge and its development in several areas of the shop, the concept used in the interviews with teachers to explain the conceptual approach. Chapters V, VI, VII, and VIII deal with representative concepts in the areas of wood, drawing, metals, and

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[1] *Ibid.*, p. 552.

electricity. Chapter IX serves as a summary of the dissertation and also contains suggestions of related but unsolved problems.

CHAPTER II

REVIEW OF THE LITERATURE RELATED TO CONCEPTS

Concept Determination

The fact that a conceptual approach to education is continuing to challenge a great many persons is plainly evident in the more recent literature. Almost invariably a feeling has existed that there is some form of higher association of experience which should elevate teaching above the presenting of facts or currently exemplary ways of doing things.

There seems to be a general agreement that to learn, man must inevitably have some direct contact with reality and that this contact must be at a level or degree sufficient to stimulate or irritate him to a state of awareness; otherwise, this contact will have no significance and it might as well have been below his threshold of awareness. That a student's reaction to a stimulation is a deeply personalized matter is also well known. Teachers can be as logical as they wish and have irreproachable evidence of the gain possible from their class presentations, but if the student is not receptive, well-laid formal plans may easily be unproductive of anything of much value.

The student's contact with reality must certainly be through his senses. How well his senses function in making him aware of data in his environment has been an area of considerable experimental research which is particularly amenable to the scientific method. Experiments concerning human perception have an extended history quite familiar to educators which is too voluminous to mention here. It is what the human personality does with his perceptions that is so very important and so difficult to assess.

Reed believes more should be done in this area, and although his experiment had reference to "set" in learning he felt it desirable to make the following observation concerning concepts:

> Although concepts are the principal tools of thinking . . . they have been the subject of many fewer investigations than have other cognitive processes for example, those relating to sensation perception imagery. . . .[1]

The difficulty of applying the scientific method to the constantly-changing human personality has caused less exacting methods to be tried, owing to the necessity of obtaining information by whatever methods seem profitable. Wegener, an educational philosopher, feels that these approaches have value:

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[1]Homer B. Reed, "Factors Influencing the Learning and Retention of Concepts. 1. The Influence of Set," The Journal of Experimental Psychology, XXXVI (February, 1946), p. 71.

> Conceptual education without the substance of perception degenerates into mere verbalism if one is not careful. Perceptual education without arriving at conceptual judgments fails to utilize that which is most important in human capacity. . . . Perception is to be distinguished from the higher aspects of ideational thinking such as imagination, judgments, remembrance and conception.
>
> What are the educational implications? Foremost, teachers should not slight either the empirical or the rational aspects of the learning process. . . . Every unit of study should have its essential concepts and percepts.[1]

There has been some sentiment in education to assume that the utility of a priori evidence should be discounted. According to Wegener, however:

> Educationally such an assumption places all of our educational theory and practice upon a strictly empirical basis. The assumption begs one of the most challenging issues ever faced by man in philosophy--the question of how we know. . . . In effect it places almost the entire emphasis of educational procedure upon a perceptual type of education.[2]

A series of excerpts selected from a publication of Edna Heidbreder on the relationship between percepts and concepts and the importance of the development of concepts appear to have enough continuity to permit them to be stated in rapid sequence:

> Specifically a concept is defined as a logical construct which through signs and symbols or both, is transferable from situation to situation and communicable from person to person.[3]

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[1]Frank C. Wegener, "Perception and Conception in Education," School and Society, LXX (July, 1949), p. 38.

[2]Ibid., p. 37.

[3]Edna Heidbreder, "The Attainment of Concepts," The Journal of General Psychology, XXXV (October, 1946), p. 173.

> Conceptual activities are modifications of perceptual processes, especially of those involved in perceiving concrete objects.[1]
>
> Yet it should be noted as a point generally accepted in psychology, that learning is importantly involved both in the perception of objects and in the attainment of concepts. . . . It should be noted that . . . conceptual activities as functional extensions of sensory perception, are among the very means by which a human being cognitively apprehends the world. . . .[2]

Lorimer, also, has similar comments to make from his investigations:

> The mind soon discovers that if various phases of reality are to form either a stimulus or a basis for its activity, they must possess other qualities besides that of mere existence. The fact of existence, being a necessary condition of all that comes within human experience, is taken for granted and not consciously realized through a process of logical analysis.
>
> Instead of the mere dead level of existence, in the experience of each individual certain parts seem to rise to actuality, certain spots seem to become foci of meaning, centers of potentiality or power.[3]

In almost the identical vein as that used in the previous quotations, Brooks makes his observations concerning the basis for motivation of concept development:

> It is reasonable that man has tended to gather these ideas of wholeness, of unity, of harmonious cooperative organization, around the centers that most immediately concern his own interests.[4]

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[1] Ibid., p. 203.

[2] Ibid., p. 303.

[3] Gerhard R. Lorimer, The Concept of Method (New York: Teachers College, Columbia University, 1910), p. 63.

[4] Daniel Ammen Brooks, The Concept of Integration (Philadelphia: The University of Pennsylvania, 1942), p. 111.

> Seemingly man has an innate ability to collate and to generalize upon his experience, using as an aid to the generalization, an ability, developed through many generations to recall and relate his own experiences and the experiences of others.[1]

According to the comments of the recent leaders cited, it becomes clear that the area of concepts in specific fields of education, although somewhat intangible could also be a rewarding one for investigation and certainly ought to receive more attention.

Industrial arts, because of its proximity to work in industry and its great stress upon manipulative shop activity, is in particular danger of having its progress arrested at the perceptual stage with the ensuing preponderance of imitative activity and stress on skills. That there must be more to the work of the world than the mere expenditure of energy is suggested by Bergson:

> Harnessed, like yoked oxen, to a heavy task, we feel the play of our muscles and joints, the weight of the plow and the resistance of the soil. To act and to know we are acting, to come into touch with reality, and even live it, but only in the measure in which it concerns the work that is being accomplished and the furrow that is being plowed, such is the function of human intelligence. Yet a beneficent fluid bathes us, whence we draw the very force to labor and to live. From this ocean of life in which we are immersed, we are continually drawing something, and we feel that our being, or at least the intellect that guides it, has been framed therein by a kind of local concentration. Philosophy can only be an effort to dissolve again into the Whole.[2]

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[1] Ibid., p. 115.

[2] Henri Bergson, Creative Evolution (New York: Henry Holt Co., 1911), p. 121.

Within the scope of this paper the frame of reference for work is that of productive industry, for industrial arts is inescapably tied to this concept of work, not only as a means of economic subsistence and progress but as a means of greater realization of the potentialities of men. That there should be a high plane for work when human beings are involved has also been explored by Dellasega. He reached the following pertinent conclusions:

> 1. Occupations pursued in behalf of social ends contain conditions in which the interactions of all workers can be guided by knowledge and therefore can be human.
> 2. Occupations conducted in behalf of social ends contain conditions for establishing the human kind of joint activity. The social ends of occupations provide common meanings for communication between special occupational groups.
> 3. Occupations pursued in behalf of social ends contain conditions for developing the individuality of workers.
> 4. Occupations are the settings for the human kind of reconstruction of the world. It is in man's occupations that he exercises his intelligence deliberately to reconstruct his physical, social, and moral world.
> 5. Occupations conducted in behalf of social ends contain the conditions for the actualization of human freedom.[1]

As Dellasega implies, man is rational and creative; therefore he is able to set goals for his work and strive to attain them by conscious effort. The goals set by man will be realistic and worthy only to the extent of man's information and his ability to organize a totality of experience.

That something of a high level is capable of occurring

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[1]Bernard V. Dellasega, "The Significance of Work in the Life of Man" (unpublished Ed.D. dissertation, University of Oklahoma, 1953), p. 111.

within the individual, and that this something, in this study called conceptualization, is located in a time sequence between the contact with reality (perception) and the response the individual may subsequently make, is suggested by Harper:

> The individual, functionally organized into various motivational states at every moment, perceives and ideates. What he perceives and ideates depends on his momentary functional organization. What his momentary functional organization will be depends upon what he perceives and ideates. The organization affects the functioning and the functioning affects the organization. Self, a conceptual "mechanism" provides one theoretical framework in which such reactive, dynamic, back-and-forth interplay can take place. Self is simply a concept. It is not a dissectable portion of the human anatomy. Such a concept, however, is valuable if it helps to systematize knowledge and suggest further research. . . .[1]

That conceptualization is a complicated process of many ramifications is again indicated by a study made of the "perception" stage. Proctor states:

> . . . The analyses showed the perceptual process to develop through at least six overlapping stages, which vary in duration from perception to perception. These six stages present in their most usual temporal sequence, are: (1) preliminary adjustment stage, (2) orientation stage, (3) explanation stage, (4) tentative meaning stage, (5) confirmation or rejection stage, (6) final acceptance stage.[2]

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[1] R. S. Harper, "A Conceptual Mechanism Intervening Between Stimulus and Response Based on a Study of the Process of Perceiving" (unpublished Doctor's dissertation, University of Oklahoma, 1952), p. 12.

[2] R. A. Proctor, Jr., "The Contributions of the Individual to the Perceptual Process" (unpublished Master's thesis, University of Oklahoma, 1949), p. 52.

Attempts to Determine Concepts for Use in Schools

From the foregoing sampling of the literature it is evident that there is agreement among a number of educators that concepts develop from percepts and that the development of concepts is a higher aim in education. If education is to be of the greatest use to the individual, the development of concepts is necessary. For some of the areas of the curriculum, attempts to determine the concepts that a student should develop during his period of education have been made over a period of many years.[1] Within recent years more attention is being given to concept development in the skill areas. For example, a new approach to teaching arithmetic has been developing with emphasis on the developing of understanding of numbers and their behavior rather than on the rules for addition, substraction, multiplication, etc., and is related to the formation of concepts.[2]

In 1957, with a large grant from the National Science Foundation and other agencies, a group assembled by the Massachusetts Institute of Technology began to write a "modern" course in high school physics based primarily upon

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[1]See issues of the Review of Educational Research. For science, as an example, the following issues are valuable: January, 1931; April, 1934; April, 1937; October, 1942; October, 1945; October, 1948; October, 1951; October, 1957.

[2]Henry Van Engen, "Formation of Concepts," National Council of Teachers of Math Yearbook (New York: Bureau of Publications, Teachers College, Columbia University, 1953), pp. 69-98.

concepts.[1]

A search of available industrial arts literature fails to reveal any previous attempts to determine a body of specific technical concepts that should be developed as parts of a modern industrial arts program. However, leaders in industrial arts education in conversations with the writer have expressed much interest in an attempt to identify concepts that can be developed, and an awareness of a need for this approach in industrial arts teaching is apparently relatively wide-spread.

Summary

A review of the more recent literature related to concepts reveals that the formation of concepts has interested a number of educators and psychologists. Unlike research dealing with perception which is responsive to laboratory techniques, concept formation seems more closely related to the field of educational philosophy.

Evidence from the writers cited indicates that (1) concepts are formed from percepts--man's contact with reality, (2) concepts have a universality which permits them to be used in many different situations, (3) groups of concepts seem to combine into still larger or more universal concepts, and (4) achieving an understanding of what a

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[1]Elbert P. Little *et al.*, "The Physical Science Study," *The Science Teacher*, XXIV (November, 1957), pp. 315-30.

concept actually is proves to be a difficult and time-consuming task of an obviously subjective nature.

Although the literature clearly demonstrates that there is some agreement as to what constitutes a concept, preliminary discussions with teachers in the field revealed that no such agreement exists among those who are not acquainted with the literature.

Because some industrial arts teachers evidenced such a variation in grasping the nature of concepts, and inasmuch as to remedy this situation would involve extensive interviews over a period of years in order to arrive at a concensus regarding concepts, it was considered essential that an illustrative concept be formed which would be compatible with the findings of this chapter. Such an illustrative concept must of necessity be in an area familiar to all of the participants of this study. The Concept of the Cutting Edge was selected for this purpose.

CHAPTER III

THE OPINIONNAIRE ON THE CONCEPTUAL APPROACH

Developing the Opinionnaire

In developing the outline for the structured interview and opinionnaire, two recent investigations conducted to gain information from in-service teachers provided some precedent and ideas for the terminology used. One concerned the attitude of teachers toward a special method of teaching arithmetic. Responses asked for were in terms of very much, some, little, or none, or by other terms showing the same sort of range.[1]

A second source of ideas was found in an article by Porter with regard to an inventory of business and economic concepts. The manner with which responses were requested is the point of interest:

> Presented here are fifty statements involving specific concepts of business and economics. At the end of each statement, space is provided for you to indicate the extent to which you agree or disagree with the concept. Indicate the extent of your agreement or disagree-

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[1]Iowa State Teachers College, "Questionnaire," (on arithmetic) (Cedar Falls: Bureau of Research, 1956). (Mimeographed.)

ment by means of the code presented here.

SA - Strongly agree D - Disagree
A - Tend to agree SD - Strongly disagree[1]

Informal disucssions with a number of high school and college teachers of industrial arts in Iowa also helped to devise the opinionnàire intended to discover the attitude of industrial arts teachers toward a conceptual approach to industrial arts teaching. In the process of formulation, a number of items in the opinionnaire were reworded because of an inability to achieve an acceptable uniformity of interpretation during these preliminary informal discussions.

Selection of Participants

A relatively large number of teaching situations were personally observed by the writer during the time this study was being anticipated and while it was in progress. From these situations, the participants were selected because it was believed that they might be able to make a real contribution. Inexperienced teachers or those with industrial arts shops in the very early stages of development were not asked to help with the opinionnaire, for it is believed that to be able to evaluate a teaching method, the teacher must have had some experience of his own in the type of situation being evaluated--in this case, the one-teacher industrial arts shop. The inexperienced teacher evaluates such a situation

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[1]Gerald A. Porter, "Inventory of Business and Economic Concepts," United Business Education Forum, IX (March, 1955), p. 18.

primarily in terms of his college training and attitudes developed as a member of a class.

The high school teachers who participated in this study were also selected because they utilized the help made available by the Field Services Division of the Iowa State Teachers College in Cedar Falls, Iowa. This division of the college provides specialists who visit schools on a consultative basis.

The college teacher-educators who participated in this study were selected because they represent the only institutions in Iowa offering major preparation in industrial arts, and because of their backgrounds and experience.

Although the selection of teachers on the basis of requests for consultative service may neither be a random sample nor necessarily represent a cross-section of the reaction of all teachers, it is valuable for the purposes of this study, for such teachers are, in general, aware of their problems and desirous of finding means of improvement. Also, it is teachers of this type who will make use of suggestions for a new approach, because teachers fully satisfied with their methods do not readily adopt new ones. Thus it seems valid to take the position that if the teachers who are interested in consultative service react favorably to the conceptual approach to industrial arts teaching, it is a method worth suggesting and pursuing. The industrial arts teacher-educators at Iowa State College at Ames, Iowa, Westmar College at LeMars, Iowa, and at Iowa State Teachers College at Cedar Falls, Iowa, present a mature array of teaching experience in the field of industrial arts teacher education.

Administering the Opinionnaire

Sampling opinion about subjective matters entirely by mail has been criticized because of the danger of inexact communication and because of the unpredictable physical-emotional state of respondents in the press of daily business. In this study no high school teacher had less than one day of consultative service, including an oral explanation of the conceptual approach with ample opportunity for him to ask questions. Respondents filled out the opinionnaire during the structured interview when the items were read orally and explained. When some teachers expressed a desire to think it through even more fully, the opinionnaire was mailed as a culmination of the personal visit and interview.

In presenting the opinionnaire and conducting the structured interview it became essential to develop an approach whereby the teachers could gain an idea as to the frame of reference in which they were being asked to consider concepts. Therefore, it was important to select a concept which could be described with reference to, and figuratively placed in, the participant's industrial arts shop situation.

Technical literature was utilized to identify a representative concept in an activity familiar to all the participants, one which could be clearly delineated as transcending perception or observation even though perceiving and observing may be inseparably involved in the acquisition of the concept. The concept of a "cutting edge" was selected and used for illustration. This concept proved very well-adapted for this purpose because all of the participants had spent considerable time with cutting as a shop activity.

General Reactions during the Interviews

Facts are seldom an exclusive stimulus to action. The complexities of personalities and the emotional tone of incidents past and present are also strong influences upon the action of teachers. As might be expected, a thread of agreement which ran through each discussion with teachers was that the individual best knew how he, himself, felt about any particular matter, and that his beliefs were a primary stimulus to action or a retardent to action.

It was believed, therefore, than an opinionnaire could gauge the attitudes with which a conceptual approach to industrial arts teaching would find itself involved in Iowa. The response, "a great many," would mean a number large enough to attract and hold the respondent's attention as a problem of some importance, urgency, or possibility. "A small number" permitted the respondent to indicate that he felt there was some quantitative importance which should be given commensurate attention but which did not have the urgency and emotional tone of "a great many." "Not significant" indicated that occasionally the matter came to attention and was then considered as not having much impact, or that it was a matter with which the respondent had had no previous dealings.

Three items appeared to elicit a yes or no answer which would represent extremes of opinion. Respondents were cautioned that consistency required the answers to these questions to also be relative.

The concept of the cutting edge aroused a sympathetic response in nearly all cases, probably because cutting activities (mainly with wood) were the dominant activities encountered in industrial arts shops in all but one case. The integration and review of the cutting edge concept in the many areas of industrial arts seemed obvious to the participants.

Considerable interest was expressed regarding the possibility of identifying other concepts besides that of mechanical cutting, equally amenable to integration in a number of industrial arts areas.

To some participants interpretation as to what constitutes industrial arts justifies the exploration of a great number of aspects of our industrial civilization. To them this makes necessary the inclusion of an equal number of areas or media to facilitate such understanding on the part of the students. Other participants feel that the line between superficiality and true understanding is a tenuous one. These latter feel, for instance, that workmanship is the essence of industry and that quality cannot be fully appreciated by a pupil who has lightly scratched the surface of an area while quickly passing on to another area and still another, especially in terms of the previously mentioned limits of the school situation.

Objective treatment of subjective matters is probably one of the most disturbing problems in all education. The teaching situations require that shop activity be started and sustained during the school year whether or not doubts exist as to direction of progress and the over-all policy. Methods the individual uses in the actual teaching situation are largely conditioned by the level of confidence he has in his sources of guidance and by his own information, skill, and leadership ability.

Shop manuals and textbooks give realistic and effective step by step instruction on how to perform various shop activities. The teacher also needs to be able to recognize the concepts to which these activities contribute. It would also seem advisable to keep a good liaison with industry particularly on a local level in order to keep shop activities up to date. Each teacher as an individual will probably continue to teach differently. It is in his professional capacity as a teacher that he may seek out the appropriate concepts for his teaching and must transcend the responsibilities of being merely mechanically skilled, important as this is, in the assisting of the pupil in achieving an accurate picture of industry.

One idea variously expressed by the teachers kept recurring, i.e., there is too much imitative activity going on in industrial arts--there is too much "do as I do" teaching without attention being directed to basic understandings. In a changing technology, specific operations in an industrial arts shop are under the constant pressure of obsolescence. If industrial arts shop activities could serve broader ends, not stopping with the acquisition of manipulative skill, so that the student could combine information and problem-solving (which in turn would encourage him to seek and use all available resources of the home and community in solving his problems) he then would become a more effective individual. In addition to being alert in perceiving what goes on about him, the student must become skillful in evaluating what he learns and in constantly integrating this effectively with all his prior knowledge. It was further pointed out by teachers that prior experience, tradition, and local custom should not be entirely minimized as a precedent for performing a shop operation. If experimental laboratory conditions could always be maintained and the research principle of the single variant adhered to, probably hard and fast procedures could be established which would have some degree of permanence. As it is, the human personality is a many-sided, complex entity; consequently, human activities are equally so.

A natural division of the total problem of practical shop activity appears to be "How you do it" and "Why you do it," the greater volume of information seems concentrated on the former. The proponents of a "how to do it" procedure are becoming more and more subject to critical scrutiny.

A conclusion reached by teachers who had a number of years of teaching experience was that ingenuity in the industrial aspects of contemporary life seems gravitating more and more towards tapping more sources of electrical power and of precision hydraulic control in lieu of hand power and high-level coordination of hand-and-eye. There is probably no truer expression of our times than that the main characteristic is "change," often very rapid change. A teacher in a one-teacher shop can easily become quite perplexed, as can any one else, by the strength and rapidity of the impact of our industrial technology. Security may be sought in teaching by retroaction. In an effort to "keep-it-simple," shop work may become unrealistic in the light of industrial changes. Electronics, for instance, has multiplied its influence to great proportions. As a large industry, power-tool carpentry has far exceeded hand cabinet-making. Many questions arise as to how these changes should affect industrial arts teaching. The teacher has a responsibility to help the students move into their rapidly changing world of technology.

Responses to the Opinionnaire as Tabulated[1]

Because of the subjective nature of concepts and concept formation it was deemed necessary to discuss each item briefly in this chapter in the light of (1) the reactions of the secondary school teachers of industrial arts to the items in the opinionnaire, and (2) the reactions of the college teacher-educators in industrial arts to each item of the opinionnaire. The reactions of these two groups are considered together so that the reactions can be conveniently considered in comparison if desired.

As may be expected, it was necessary to discuss at length the nature of concepts and concept formation before a frame of reference could be established in which to obtain data. Following this, each item of the opinionnaire was discussed to be sure it was understood by the participants as well as possible.

Interpretation of the Responses to the Individual Items in the Opinionnaire

Because of the subjective nature of concepts and concept formation it was deemed desirable to discuss the

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[1]The tabular data obtained during the structured interviews are compiled in Table 4.

TABLE 4

RESPONSE OF SIXTY-FIVE HIGH SCHOOL TEACHERS AND FIFTEEN COLLEGE TEACHER-EDUCATORS TO THE OPINIONNAIRE ON THE CONCEPTUAL APPROACH TO INDUSTRIAL ARTS TEACHING

Items	Teaching Positions					
	High School			College		
	A great many	A small number	Not significant	A great many	A small number	Not significant
1. Do you feel there have been industrial arts activities, procedures, and operations carried on in your shops producing interpretations by your students which will be obsolete in four years or less?	17	39	9	2	12	1
2. Do you feel there are certain <u>enduring</u> concepts of industrial processes which your industrial arts activities can implement?	59	6	0	11	4	0
3. Do you feel there are certain concepts of industrial processes which a number of your industrial arts areas can <u>combine</u> to develop?	49	16	1	11	4	0

TABLE 4--Continued

Items	Teaching Positions					
	High School			College		
	A great many	A small number	Not signif-icant	A great many	A small number	Not signif-icant
4. As time went on, have you found it necessary to discard some activities in industrial arts because they did not help to develop basic understandings of industry within the time limits of your courses?	8	43	14	4	9	2
5. Has it been your experience that any given areas of industrial arts are superior to others in helping students to develop basic understandings of industrial processes and methods?	16	37	12	5	9	1
6. Within the time limits of your courses, do you feel that industrial concepts are best developed by having ten or more areas in your industrial arts shops?	3	14	48	3	5	6
7. Do you feel that industrial concepts are best developed by having five to nine areas in your industrial arts shops?	24	32	9	10	5	0

TABLE 4--Continued

Items	Teaching Positions					
	High School			College		
	A great many	A small number	Not signif- icant	A great many	A small number	Not signif- icant
8. Do you feel industrial concepts are best developed by having four or less areas in your industrial arts shops?	36	14	14	2	3	10
9. Do you feel there are important industrial concepts and under- standings which will manifest themselves to the pupils through shop activity although this ac- tivity is not consciously direc- ted at developing these concepts?	25	34	6	1	11	3
10. Do you feel there are shop manip- ulative activities which are ir- relevant so far as developing concepts of industry are con- cerned?	23	39	3	3	10	2
11. Do you feel there are deeply in- teresting shop activities which have little value as far as developing concepts of industry are concerned?	20	37	8	12	2	0

TABLE 4--Continued

Items	Teaching Positions					
	High School			College		
	A great many	A small number	Not significant	A great many	A small number	Not significant
12. Do you feel you have shop activities of great service to other aims of industrial arts but which provide meager development of concepts of industrial processes?	24	38	3	9	5	1
13. Do you feel your industrial arts shops should stress an understanding of industry more than the other objectives of general education which it shares with the rest of the school?	40	21	3	12	3	0
14. Do you feel there are shop activities of a "handicraft" nature which interpret industry enough to merit inclusion in your shop on this basis?	4	40	21	2	8	5
15. Do you feel the handwork done in your industrial arts gives understanding of industrial production methods commensurate with the time spent on it?	6	40	19	3	9	3

TABLE 4--Continued

Items	Teaching Positions					
	High School			College		
	A great many	A small number	Not signif- icant	A great many	A small number	Not signif- icant
16. Do you feel manipulative activities give your pupils a more accurate picture of life in industry than does a more verbal approach?	52	12	1	10	3	2

reactions of the participants to each item of the opinionnaire as well as to tabulate them. Therefore, an item by item discussion will follow.

1. Do you feel there have been industrial arts activities, procedures, and operations carried on in your shops producing interpretations by your students which will be obsolete in four years or less?

"Interpretations" are here viewed as any inferences the student may make. If the inferences happen to be the ones intended by the teacher, has he abandoned a great many, a small number, or an insignificant number? In responding, the teachers invariably pointed out that they were answering on the basis of past experience in many situations and they would not have knowingly accepted any such unproductive interpretations as were in their power to avoid.

Both the industrial arts teachers and the college teacher-educators clearly feel that only "a small number" of the interpretations by pupils will be obsolete in four years or less.

2. Do you feel there are certain <u>enduring</u> concepts of industrial processes which your industrial arts activities can implement?

This item gives the teachers an opportunity to express their opinion as to the feasibility of finding a body of concepts related to industry upon which to build a curriculum.

A concept in this sense is a group of organized, integrated perceptions which have undergone teacher evaluation and have utility in the opinion of the teacher. That these concepts may endure might be indicative that the teacher has repeatedly tested some of them against industry and has not rejected them.

Considerable confidence in the ability of industrial arts teaching to produce concepts which are sound and which will endure is indicated by the fact that all but six of the high school teachers and all but four of the college teachers indicated that they felt "a great many" enduring concepts were possible. The others said that they felt "a small number" would endure.

3. Do you feel there are certain concepts of industrial processes which a number of your industrial arts areas can <u>combine</u> to develop?

This item attempts to ascertain the degree of integration the total activity in a one-teacher industrial shop might possess. It is the opposite of compartmentalization into units such as woodwork, metalwork, etc., insofar as concepts are concerned.

All but seventeen of the high school teachers felt that there were a "great many" concepts which industrial arts areas could combine to develop. All but four of the college teachers felt the same way. Only one person, a high school teacher, indicated there was a "not significant" number which could be thus achieved.

4. As time went on, have you found it necessary to discard activities in industrial arts because they did not help to develop <u>basic</u> understandings of industry within the time limits of your courses?

If the teacher indicated that certain industrial processes were carried out, but then discarded because they were not productive of concepts of utility in understanding the methods of industry, or because they consumed an unwarranted amount of time or were just "training of hand and eye," that teacher was very likely aware of the impact of our rapidly-changing industrial picture, in which basic understanding could be the principal asset. If the consistent answer would be "a great many," it would probably indicate a trend away from manual training as older philosophies of industrial arts have become abandoned.

Most of the high school teachers felt that only a small number of activities had been discarded because of failure to help develop basic understandings of industry. Fourteen felt they had discarded a "not significant" number. Nine college teachers felt they had discarded "a great many" and four had discarded a "small number" of such activities.

5. Has it been your experience that any given areas of industrial arts are <u>superior</u> to others in helping students to develop basic understandings of industrial processes and methods?

It was not considered to be the purpose of this opinionnaire to tabulate a census of <u>what</u> areas are felt to be superior. For instance, if "a small number" were checked, it might be indicative that a small number of areas <u>could be</u> identified in a future study and then this small number capitalized upon for better utilization of the school time allotment for industrial arts. If "a great many" were checked, it indicated that opinion favored a large number of offerings which could be selected at random from the great many areas which have been taught in industrial arts.

The opinion of the high school teachers was that a "small number" of industrial arts areas are actually superior to the many others that have been taught. Sixteen teachers, however, felt that there were "a great many" superior areas. Twelve felt that no particular areas were superior to others. The college teachers held to this view for the most part, although one of them felt there were no significantly superior areas for developing concepts of industry.

6. Within the time and other limits of your courses, do you feel that industrial concepts are best developed by having ten or more areas in your industrial arts shops?

7. Do you feel industrial concepts are best developed by having five to nine areas in your industrial arts shops?

8. Do you feel industrial concepts are best developed by having four or less areas in your industrial arts shops?

Questions 6, 7, and 8 represent a rather interesting issue as to the number of areas to be included in a one-teacher shop situation. Each teacher is deeply enmeshed in the local and state school atmosphere, and this seems very much a personalized matter.

If the column "a great many" was checked as an answer to question 8, it indicates that in his school situation the teachers felt more concepts would result from having four or less areas than from having, for instance, ten or more. A fair assumption would be that his professional integrity would cause him to try to install ten areas if he felt more concepts would result.

The high school teachers feel that "a great many" concepts could be developed by having four or less areas and conversely feel that a "not significant" number could be achieved by having ten or more areas. Five to nine areas is next favored as concept-producers, but only "a small number" of concepts was felt possible in these five to nine areas because of the many practical limitations of the school situation.

The college teacher-educators felt five to nine areas would produce a "great many" concepts whereas ten or more areas would produce either a "small number" or a "not significant" number. They also felt that having four or less areas would likewise produce either a "not significant" number or perhaps a "small number" of concepts.

9. Do you feel that there are important industrial concepts and understandings which will manifest themselves to the pupils through shop activity although this activity is <u>not consciously</u> directed at development of these concepts?

If the teacher felt that the pupils are <u>automatically</u> making worthy associations from the industrial arts shop activity to industrial processes, he might be inclined to check "a great many." On the other hand, if he felt that he must constantly assist the pupils in making these associations, he might check "a small number." This feeling would no doubt be guiding him in the conduct of his teaching.

Thirty-four of the high school teachers concluded that only a "small number" of concepts would manifest themselves to the pupils without having the instructor consciously strive to help them associate their industrial arts activities with industry. Only six felt that a "not significant" number would be thus manifested. On the other hand, twenty-five felt that a great many concepts would manifest themselves automatically. The college teachers, however, held that only "a small number" of concepts would automatically manifest themselves.

10. Do you feel that there are shop manipulative activities which are irrelevant so far as developing concepts of industry are concerned?

This question samples the belief as to the amount of shop activity that may be serving other worthy ends but at the same time slighting the industrial aspects of industrial arts, in view of the fact that the school situation puts a limit on the total amount of activity attainable in the shop. Also some of these irrelevant activities could represent to the teacher something in the nature of busy-work.

Thirty-nine of the high school teachers felt there were only "a small number" of irrelevant shop activities going on. Twenty-three, however, felt there were a "great many" irrelevant activities; only eight considered the amount of irrelevant activity to be "not significant."

Three of the college teachers indicated that they believed that there were "a great many" irrelevant activities. More important, ten held that there were a "small number," whereas only two felt that there was a "not significant" amount of irrelevant activity.

11. Do you feel there are deeply interesting shop activities which have little value so far as developing concepts of industry are concerned?

The intention here is to sample the belief as to the amount that the aim of industrial arts, to assist the pupil in understanding industry, is being pushed aside by other activities such as hobbies, craft enthusiasms, and fads.

Thirty-seven of the high school teachers thought there were only a "small number" of deeply interesting shop activities which had little value so far as developing concepts of industry is concerned. Twenty, however, felt there were "a great many" and only eight a "not significant" number.

Twelve of the college teachers felt there were "a great many" of such activities with but two of these college teachers holding there were "a small number." None of the college teachers considered there was a "not significant" amount of dilution of this aim.

12. Do you feel that you have shop activities of greater service to <u>other aims</u> of industrial arts but which provide meager development of concepts of industrial processes?

If the teacher checked "a great many," he probably feels that "understanding" industry can give ground to these other aims, inasmuch as the total time in shop is limited. Industrial arts activities could then, presumably, assume something of the social-studies outlook.

More than half (thirty-eight) of the high school teachers believe that only "a small number" of otherwise useful activities did not develop concepts of industrial processes also. Twenty-four of these instructors, however, felt there were a "great many" activities which did not contribute to developing an understanding of industry.

The college teachers generally agreed there were a "great many" activities which were useful but did not develop concepts of industrial processes. Five felt there were "a small number," and only one felt the number of such activities was "not significant."

13. Do you feel that your industrial arts shops should stress understandings of industry more than the other objectives of general education which it shares with the rest of the school?

If the teacher checked "a great many" he indicates that he feels that concepts assisting pupils to understand industry are important and unique to his industrial arts shop and therefore should be stressed but at the same time he should not necessarily ignore the other aims of industrial arts.

By a considerable margin, forty of the high school teachers felt a "great many" industrial understandings should be stressed rather than only a small number. Only three felt that a "not significant" stress should be placed on understanding industry. Twenty-one felt a "small number" of industrial concepts are sufficient in view of the total aims of industrial arts.

The college teachers plainly indicated they felt a "great many" of such understandings should be stressed. Only three felt a "small number" should be so stressed, and none felt that industrial concepts were "not significant" in this light.

14. Do you feel there are shop activities of a "handicraft" nature which interpret industry enough to merit inclusion in your shop on this basis?

If the teacher checked "a great many" in answer to this question, he probably feels that hand work such as weaving, leather tooling, art metal work, and a number of other activities thought of as the crafts in the industrial arts vocabulary are important enough to absorb time which could otherwise be used by activities of an industrial, machine-operation nature.

In the case of the handicrafts, both groups of teachers felt that only "a small number" assisted the pupil enough in interpreting industry to warrant inclusion in the industrial arts program on this basis. Five of the college teachers felt there were a "not significant" number of handicrafts which could be included in an industrial arts program to efficiently contribute to developing an understanding of industry.

15. Do you feel handwork done in your industrial arts gives understanding of industrial production methods commensurate with the time spent on it?

This question attempts to differentiate handwork involving the use of the handtools of industry, such as the hacksaw, file, and hand drill, from power-driven tools and from handicraft activities.

In almost the same pattern as found in question fourteen, both groups felt only a "small number" of activities of a handwork nature gave sufficient understanding of industrial production methods. In addition, nineteen high school teachers and three college teachers felt the number of such handwork activities was "not significant."

16. Do you feel that manipulative activities give your pupils a more accurate picture of life in industry than does a more verbal approach?

The attempt here is to get an indication of the importance the teacher attaches to the physically manipulative aspects of industrial arts classes.

Both groups of teachers left little doubt but that "a great many" manipulative activities were superior to a more verbal or vicarious approach so far as an accurate picture of industry is concerned.

Summary of the Results of the Opinionnaire

College industrial arts teacher-educators in Iowa feel that "assisting the pupil to understand industry" is a dominant role that industrial arts should play. High school teachers in Iowa agree in part but are inclined to place this aim on an equal plane with other aims of pupil development.

Both groups feel confident that the results of their shop activities can be made to endure and that effective concepts can be achieved in spite of some hindrance from the amount of irrelevant activity now found in industrial arts shops.

Both groups hold that there must be some areas of industrial arts which are better adapted to the school industrial arts shop situation than others. Which areas these actually are would assuredly be a worthy problem for extensive investigation.

The two groups agree that there are activities of great personal interest and of a hobby or handicraft nature valuable from many viewpoints; at the same time such activities constitute a danger in that they sway industrial arts shop activity away from its major responsibility, to assist the pupil in understanding industry.

Both groups seem alert to the idea that too much emphasis in the use of handtools may not accurately picture industrial production methods.

The high school teachers are inclined to feel that the students will gain some insights into industry from industrial arts shop work without the teachers continually having to provide help in this association. However, the college teachers doubt this. Ostensibly, help from the teacher in this respect should generally be forthcoming.

The high school teachers indicate that they believe that in view of the many limitations of the practical school situations in Iowa, more concepts of industry will probably result from having four or fewer areas of industrial arts activity. College teachers consider that five to nine such areas will result in more concepts. Both groups agree, though, that ten or more areas would be unworkable under the usual school circumstances.

The college and high school teachers differ (1) as to whether or not assisting the pupil to understand industry is the dominant role of the industrial arts program; (2) as to whether or not students will gain many concepts without the help of the teacher; and (3) on the number of areas that are feasible in a one-teacher shop. These differences probably arise from two causes, the formal training of the college teachers and the lack of recent contact and a complete realization of the limitations, working conditions, and student motivation difficulties involved in the high school situation. Because of formal training the college teachers feel more competent and confident to teach more areas. Because of more formal training they may have a better understanding of concepts and consequently of industry, and they give this aim a higher priority. Because they are less directly in touch with high school students, the college teachers are probably less swayed by the changing interests and enthusiasms for hobbies and crafts. They are more detached from the multitude of practical problems besetting and perplexing high school teachers.

CHAPTER IV

THE CONCEPT OF THE CUTTING EDGE

The Basis for Selecting Specific Concepts

Material for this part of the dissertation has been drawn from the writer's experience in teaching industrial arts, from informal discussions with the teachers visited during the period of travel for the Iowa State Teachers College Field Services Division, and from a search through the literature written for industrial arts classes and for craftsmen in the various industrial areas, to determine concepts the writers considered important enough to use.

In selecting concepts from the literature, no count was made of the number of times any one concept appeared. While inclusion by many authors is an indication of the importance on a concept, knowledge and applications change so much that popularity does not seem a valid criterion for selection. In selecting the quotations to illustrate the concepts the choice was usually given to a writer of outstanding reputation or whose wording seemed most applicable to the industrial arts teachers and students. Because one author is quoted, however, does not indicate that other authors did not also include the idea. In some cases no author seemed to summarize the concept adequately; in these instances no specific reference is cited.

No attempt has been made to make the list of concepts in each area exhaustive. Nor has there been an attempt to rank the concepts with relations to relative importance or degree of complexity and development. It is recognized that some concepts are subsidiary to others and contribute to their development, but no ranking on this basis has been attempted. It is believed that no such exhaustive lists nor ranking of concepts can be attempted at the present stage in the development of the conceptual approach to industrial arts teaching. Many teachers will need to try this program with many students before it is known with much certainty which concepts have lasting value and importance, which must precede others, and which are most valuable in the development of an understanding of industrial processes. At the present stage of experience with this type of program such evaluation of individual concepts must largely be individual opinion and therefore subject to disagreement.

Mechanical Cutting in General

The concept of cutting mechanically with an edged tool is probably one of the most common industrial concepts illustrated in industrial arts shops. The application of a cutting edge to a material in order to remove the excess is one of the most fundamental and far-reaching in our industrial life today. Such an activity seems to maintain popularity in the face of a rather large number of new industrial methods of shaping materials such as the applications of pressure, heat, or laminating procedures. The manipulative activity which goes on in the application of a tool is the essence of a large portion of an industrial arts program. The forms that this activity takes can result from imitation of the instructor, tradition, or from almost any other stimuli. The shaping of wood with cutting edges of various sorts was by far the most common activity engaged in by students in the industrial arts shops observed during the visits to schools in Iowa. Consequently, the concept of the cutting edge was selected as the explanatory example of an industrial arts concept for use in the conversations and interviews with industrial arts teachers. The application of cutting edges to wood formed the basis for the introduction of the conceptual form of teaching. This chapter includes the concepts related to the cutting edge that were discussed with the teachers.

Teachers are aware of some basic tenets, such as the principle that a material can best be mechanically cut by an edge which is harder than the material to be cut. Some of the understandings leading the enlargement of this concept are, for example, that wood is usually shaped by carbon steel-edged tools or by alloy steel tools such as carboloy and high speed steels. In turn, edges are usually formed on such tools by grinding wheels made of materials such as carborundum, or aluminum oxide. Each grain of these wheels constitutes a small cutting edge in itself held in place by the bond of the wheel and is harder than the tools to be ground. One accepted way of shaping grinding wheels is by use of industrial diamonds, harder than the crystals of the grinding wheels; with proper support they can, therefore, shape the wheel. Diamonds, in turn, are shaped by diamond grains imbedded in copper lap wheels. Modern research is even now searching for synthetic crystals harder than industrial diamonds and thus suitable to be used to shape diamonds or to be mounted in holders so that they too may be used for industrial material cutting.

It is largely the opportunity of engineering and research laboratories today to discover better ways of achieving the edge and of means of applying it effectively. However, it is also possible that engineering and research laboratories will be staffed by people who received their original interest in this work through activities at school in the industrial arts shop. Familiar in the concept of cutting is the principle that decreasing the area of the apex of the cutting edge proportionally reduces the power required to drive the edge into the material, either cellular or crystalline. The reduction of the power required in the case of sharp hand tools greatly increases the ease with which a tool is controlled. Industrial arts teachers commented again and again, "A sharp tool is a safe tool."

Most of the participants knew that the angle to which woodworking tools are usually ground is a compromise adjusting keenness of the edge to serviceability in terms of the hardness of the tool, the hardness of the material being cut, and the amount of power to be applied at a given rate. The dimensions, including keenness, angle, clearances and rakes, were generally accepted from the tool manufacturers without question.

The change in dimensions and angles of a tool under changing circumstances, for example the cutting of tool steel in a metal cutting lathe with a carboloy lathe bit, seemed less well understood, especially the phenomenon of the built up edge wherein the accumulation of bits of the metal in an area just back of the apex of the lathe tool is crucial in the production-line removal of excess material from the stock. This accumulation tends to retard the dulling of the tool.

In examining each industrial arts shop with the industrial arts teacher, many opportunities presented themselves to illustrate the modifications of cutting edges to suit special tasks ranging from the skiving of leather with a thin bladed skiving knife to the machining of steel in a shaper with a high speed steel tool of low angled clearances and rakes.

On the basis of information received by means of the discussions with the teachers, it appears that there is need in the industrial arts shops for a conscious development of an understanding of the cutting edge and the processes involved in applying cutting tools to materials. Teachers and students both had some of the concepts related to cutting, but many of the detailed points seem to be much less well-known. This chapter will offer some further suggestions concerning the ramifications of the understanding of the cutting process and cutting edges as they occur in various parts of the industrial arts shop.

The Applying of a Cutting Edge

Applying a cutting edge to material, no matter what it is--wood, metal, ceramic, stone, or glass--has the purpose of removing part of the material to allow it to be given a desired shape. The edge may take the form of a knife for removing small chips, of a saw for cutting the material to the desired size, of an abrasive machine for removing small irregularities or for making the material round or smooth, of hand powered abrasives for smoothing final rough spots, of a plane for smoothing larger irregularities, of a chisel for removing chips, or a drill for making holes; in each case the cutting is to remove material that is excess to the desired form. The cutting edge, no matter what its form, may be applied by hand power through the traditional hand tools or by machine power as is favored in industry. There is an ever-increasing trend to use small electrical power tools in many shops and in the construction industry. Whatever the source of power, the cutting edge still remains basically the same in principle.

Two basic concepts regarding the edge itself emerge. Further concepts that will develop with the activities within the industrial arts shop are more closely tied to the applications of the edge in the different forms that it takes. It is important that the student learn to recognize the common features of the cutting edge in whatever situation he meets it. If this is accomplished, the cutting in whatever form or on whatever material it will operate will be accomplished with intelligence and greater skill than if the concepts were not part of the background of the individual.

In this chapter the concepts related to the cutting edge will be discussed under the following two divisions: (1) concepts related to and applicable to all cutting edges, and (2) concepts related to specific tools which have a cutting edge. In each case the changes in the cutting edge that are met with changes in the material cut will be considered. It is recognized that the more contacts a student has with various cutting edges the broader will be the concept developed. Some or all of these concepts were considered in the discussions with the teachers to illustrate the possibilities of developing concepts across several areas of the industrial arts shop. The edge must change its substance, character, and approach as it performs present day functions in each area. The tool must be abreast of modern technology and take its cue directly from industry if gaining an understanding of industry is to remain a prime pupil objective.

The opportunities for providing insights into cutting seem quite great, probably beginning with the pupil's first experience with ordinary whittling. Each time an edged tool comes into use in any area of the industrial arts shop, the concept can be reviewed and enlarged upon to provide the integration and unity needed for functional knowledge.

Concepts Related to and Applicable to All Cutting Edges

As indicated previously, the concept of the cutting edge was chosen as an example of how a concept might be developed in industrial arts teaching because it was one with which most teachers would be most familiar. In addition, it is one which runs through many areas of an industrial arts shop. This is true because certain basic concepts apply to all cutting edges no matter what form they may take or upon what material they are used. While these concepts may not be the first to develop within a student and to grow with each contact with a cutting edge in a new situation, they are considered first because of their ramifications and applications to the tools to be considered in another section of this chapter.

Concepts that apply to all cutting edges and which are elementary enough so that they probably should be developed in the industrial arts shop are:

1. The concept of the relationship between the material to be cut and the material of the cutting edge.

2. The concept of the necessity for and type of support for the cutting edge.

3. The concept of the maintenance of the cutting edge.

The Relationship between the Material of the Cutting Edge and the Material to be Cut

The relationship between the tool and the material to be cut seems so obvious that there should seem little need to consider it as an important concept to develop in the industrial arts shop. Of course, in order to cut efficiently a material must be harder than that which is being cut. However, the very obviousness of this concept may actually cause it to be ignored in practice. If asked, the student would probably give a right answer, but in selecting tools and caring for them, he often does not illustrate that the words have true meaning to him. Many students will not distinguish between a saw for wood and a saw for metal. If a saw is needed, whichever is handy is likely to be used. Many tools have been ruined by use on the wrong material because the student did not realize the importance of the fact that cutting tools are made for specific jobs and should be used on the material for which they are adapted.

The nature of the material composing the tool always involves a principle that, traditionally speaking, the cutter must be of a material harder than the material which is to be cut. The ability of the cutter to resist breakage and deformity by stresses and abrasion is a determiner of how much of a taper or what degree of sharpness the edge can be given. Smoothness of cut, power required and time involved, including the restoring of a worn edge and the initial cost of the tool, are also considerations in selecting material for tools.

Many woodworking hand-tools are now made from high carbon steel. With proper heat-treating they appear to be suitable for normal operations. Woodworking power tools, subjected to especially severe stresses, are apt to be made of other alloy-steels or of compressed carbides.

The ability of the woodworking tool to retain its edge under the stresses of cutting is determined by its hardness, toughness and shape. If one seeks hardness primarily, the edge may become brittle enough to break or may become so hard that it is difficult to sharpen. The tool then becomes less suitable. Tools which are soft, hence easy to sharpen, may be inefficient because of frequent delays for sharpening. Grinding at a shallow angle in an effort to get greater keenness at the apex may remove enough metal to cause the thin edge to deform or break. Hence the shape and angle of the edge for each tool is determined by the kind of material to be cut and the rate of cutting. The material to be cut is also a determiner of what material is to be used for the cutter. Cutting tools, to be economical, are usually made of a material no more expensive than is absolutely necessary.

Extremes are useful for illustration. For example, leather is cut easily with a knife which has a thin blade and a long taper leading to a keen edge. This is possible because leather is soft and offers little resistance to a sharp blade. Machine steel in a metal-cutting lathe, on the other hand, required a tool of a tough, hard alloy such as high speed steel.

The Cincinnati Milling Machine Company indicates the qualities desirable for metal cutting materials:

> Metal-cutting materials, as their name implies, perform the function of cutting. To discharge this function satisfactorily, these materials must be <u>stronger</u> and <u>harder</u> than the material to be cut, and sufficiently <u>tough</u> to resist shock loads resulting from the cutting operation.
>
> They must also have good resistance to abrasion, permit a keen cutting edge, provide reasonable tool life and retain a high degree of hardness at the temperature developed during cutting, a quality known as <u>red-hardness</u>.
>
> The cutting tool materials available possess these qualities in varying degree. For example, some of the materials have high hardness, moderate strength and toughness, and good wear resistance. Others have high strength, moderate toughness, high resistance to wear and high red-hardness.
>
> All of the desirable qualities are not found in any one material, and the selection of the cutting material to use in a particular application depends to a certain extent on its properties. This has resulted in the development of a large variety of cutting

materials. . . .[1]

As a matter of fact, in metal machining a new concept of the built-up edge is possible in which the cutter itself does not actually do the cutting once the built-up material adheres near the edge.

Lapping operations with lap-wheels offer another variation of cutting edges. Materials such as carboloy have few ordinary materials harder than they are. Carboloy lathe bits are ground (sharpened) with diamond "dust" imbedded in a lead or copper wheel. The edges of each speck of diamond dust can abraid (grind) the surface of such a carboloy cutter, or even grind other diamonds if called upon to do so. Semi-precious stones, rocks, etc., can be cut with a thin wheel of this type and polished by this material on the face of a revolving disc. Glass can be easily drilled by imbedding carborundum (and other) crystals in the end of a copper tube held in a drill press chuck. The grains are kept from scattering with a dike of putty around the proposed hole. In each case the material of the cutting edge is suited to the material to be cut.

Young in this manner summarizes the types of materials used for cutting tools and the uses of each:

> Cutting tools are made from various materials, some of the more common of which are listed here,

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[1]A Treatise on Milling and Milling Machines (Cincinnati, Ohio: The Cincinnati Milling Machine Company, 1951), pp. 75-76.

HIGH CARBON STEEL. 0.9 to 1.2 C (carbon). Operates up to 400 F. Confined mostly to taps, dies, and small drills where production is small or where excessive breakage is apt to occur. Very generally used for wood and other soft material.

HIGH SPEED STEEL. A typical steel contains 18 w (tungsten), 4 CR (chromium), 1.0 V (vanadium), and is used very widely for general metal cutting.

NONFERROUS ALLOYS. Stellite is an example. It contains 13.5 W, 40.5 Co (cobalt), 32 Cr with smaller percentages of Ni, Mn, C, and Fe. These alloys remain hard up to 1500 F, a property known as red-hardness.

CARBIDES OF TUNGSTEN, TANTALUM, ETC. An example is Carboloy and a typical analysis is 5.3 C, 12.7 Co, and 1.4 W. Used for high production, high speed work or where the same tool can be used on a number of different jobs. Also used for cutting very hard, nonmetallic materials. Because of high cost and brittleness, bits are generally brazed to a carbon steel body.

ABRASIVES - ALUNDUM. Silicon carbide, SIC and aluminum oxide, Al_2O_3. Are generally bonded to form grinding wheels and honing tools. Each grain constitutes a small cutting bit in itself.[1]

How this concept of the cutting edge is modified as cutting is done in the various areas of an industrial arts shop whether by hand or machine provides opportunities for review, integration, and reinforcement. As a student approaches the use of a new material the teacher should call attention to the differences in the tools that are used. In the supervision of the shop the teacher should insist that tools are used only for the materials for which they are planned. Comparative cost of tools for cutting wood and cutting steel might also help the student to realize the importance of each.

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[1] James F. Young, Materials and Processes (New York: John Wiley & Sons, Inc., 1944), p. 536.

Support for the Cutting Edge

Although the concept of the relationship between the material of the cutting edge and the material to be cut appears fairly obvious, the related one of the need for support for the cutting edge and the variation of the support according to the material cut seems less well recognized. As Burghardt and Axelrod say,

> The action of any cutting tool in any material is that of a wedge prying apart or separating the substance of the material. The angle of the wedge is the cutting angle of the tool.
>
> The harder the material to be cut, the more the cutting edge must be supported, that is, the cutting angle must be greater. The cutting angle that is correct for wood is not substantial enough to stand up under the strain of cutting iron or steel; the cutting edge not being sufficiently supported against such a severe crushing force.[1]

Most students will have used wedges and levers and will realize that for these to reach their full effectiveness in use they must be thick enough or strong enough to withstand the pressures exerted upon them.

Again reference may be made to the skiving knife which has a thin blade and a long slope of the wedge for the cutting of leather. Or attention might be called to the familiar kitchen knives. The bread knife has a thin blade and a small cutting angle. Chopping knives have a heavier blade and a greater cutting angle. Looking at other cutting

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[1]Henry D. Burghardt and Aaron Axelrod, Machine Tool Operation, Part I (New York: McGraw-Hill Book Co., Inc., 1953), p. 292.

tools in the shop can make the students aware of the variation in the thickness of the tool and the size of the cutting angle. A comparison of a chisel for cutting wood and a cold chisel (for cutting metal) as to thickness of the base, and steepness of the cutting angle will help the student further visualize the manner in which the support for the cutting edge varies with the material which is to be cut.

Most students will find this variation quite logical after it is called to their attention. They will realize the difference in the amount of force that must be exerted to cut wood or to cut steel. Recognizing the difference in force involved, they will recognize the need for the support for each type of edge. Young indicates something of the range of the force that develops in metal cutting operations:

> Tremendous forces are involved in the shearing or tearing action with which a metal chip is peeled off in machine operations. The magnitude of these forces varies with the material, tool shape, and size of chip. Investigations by F. W. Taylor show that 35 to 99 tons per sq. in. of chip cross-section (depth of cut multiplied by its width) were required for machining cast iron, and 92 to 168 tons per sq. in. for machining forged steel.[1]

He then points out that the engineer who designs metal parts that need to be machined should be sure that his design provides sufficient working space for sturdy, rigid, and well-supported tools.

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[1]Young, op. cit., p. 534.

Ansley briefly describes various machining processes and includes the following:

> One limiting factor in the cutting speed of machine tools is the material of the cutting tool itself. The first major improvement in tool materials was the introduction of the tungsten carbides about 1929. It was almost ten years, however, before new and more rigid machines were developed to take full advantage of the possibilities of carbide tooling. When this was accomplished, the cutting speeds commonly used on iron and steel were increased from the 75 to 150 surface feet per minute of high-speed steel tools to 300 to 600 ft. or more for carbide tools.
>
> The introduction of ceramic and other cemented oxide cutting tools promises a comparable further development. . . . it was not until 1955 that promising results were obtained in machining steel. . . . Most favorable results have been obtained around 1000 surface feet per minute although 2000 to 3000 ft. have been used. . . . brittleness of ceramics has been the chief difficulty, and this requires that small inserts of the ceramic be supported very rigidly in metal shanks.[1]

Visits to machine shops to see other metal working tools and to compare them with the more familiar wood working tools might also help the student develop an awareness of the need for support of the cutting edge. This concept should very likely result in decreasing the damage to woodworking tools in the shop because some student tried, for instance, to use them for metal working.

Related to the recognition of the need to support the cutting edge in the tool is the recognition that the material being cut also needs to be supported as adequately as possible. If the cutting edge cannot work well without support,

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[1]Arthur C. Ansley, Manufacturing Methods and Processes (Philadelphia: Chilton Company, 1957), pp. 143-144.

it cannot work at its best if the material being cut is not supported. The fact that unsupported work is difficult to cut is a reality ignored by some students in various degrees, from using rickety vises to failure to saw as close to the vise jaws as possible. The teacher should watch for any misuses or incorrect uses of tools and correct them as soon as possible. In making the correction the reasons for the difference should be explained.

The Maintenance of the Cutting Edge on Tools

During the discussion of the concepts related to the various cutting edges mention will be made of the necessity of developing an understanding of the use of each type of edge and of an appreciation of the tool that will lead to the proper care of it. With use, all cutting edges normally will become dulled. The harder the material from which the edge is made the less often the tool will need to be sharpened, but, also, the more difficult the sharpening will be. However, students should learn to care for the tools that they use so that the cutting edges are not damages by misuse and carelessness. The old saying that "a workman is known by his tools" should come to have meaning for them. It may take considerable explaining on the part of the teacher to instill some of this feeling. Of course, the teacher must also exemplify respect for the tools and equipment of his industrial arts shop.

Students should certainly learn how to sharpen a pocket knife. Whereas this may not be an activity related to industry, they may be called upon to use such a skill often. In sharpening a knife the basic principles of any sharpening process will be learned. To sharpen a cutting edge the tool is abraided against a harder material to remove enough of the metal to allow the edge to become thin and sharp again. As the edge is made sharper the force needed to enter this edge into the material to be cut becomes less and less. When the edge of a woodworking tool becomes dull, the force needed to make it cut becomes much greater. It becomes progressively harder to accurately control this greater force by hand. Finally, if the tool becomes too dull, the pressure needed becomes so great that the material actually becomes torn and shredded instead of cut.

In essence, however, with respect to this edge, each time the edge of a woodworking tool is applied to the grinder or sharpening stone at a predetermined angle, the metal remaining at the apex of the angle formed by the sharpening activities becomes thinner and thinner until finally the edge cannot be seen without optical magnification. As this dimension is approached on the grinder, a wire edge is formed which can best be removed by hand honing.

Herman Hjorth effectively shows by pictorial illustration how even a cabinet scraper must be brought to an edge by draw-filing, honing, and burnishing.[1] Turning-over the edge of the cabinet scraper with a burnisher to permit a readily controlled, smooth cut is necessary also.

Further in this connection, Hjorth says, "The sharpening of a cabinet scraper falls into three divisions: grinding, whetting, and bending the edge."[2] He evidences here that once an understanding is formed as to the functions of the edge, other tools, i.e., a grinder, can be used to serve the purpose. He goes on to point out also: "A burnisher is simply a bar of smooth, hard steel. An excellent burnisher can be made from an old triangular file by grinding away the teeth and rounding the corners slightly."[3] To the experienced industrial arts teacher this homely example of devising a tool by knowing its function would seem perfectly obvious.

Other woodshop hand tools readily illustrate cutting edge concepts in their maintenance. Hjorth in this fashion indicates how to recognize a dull edge:

> When a plane iron or other cutting tool becomes dull its edge shows a fine, white line. If a tool is sharp its cutting edge is invisible. It should be made a rule . . . before using a plane or chisel always to look at its edge.[4]

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[1]Herman Hjorth, Basic Woodworking Processes (Milwaukee: The Bruce Publishing Co., 1948), pp. 13-16.

[2]Ibid., p. 14.

[3]Ibid.

[4]Ibid., p. 11.

It is doubtful that a student in an industrial arts shop should be asked to develop the skill necessary to sharpen many of the more specialized tools that are used in the shop. He should, however, understand the sharpening process and appreciate the skill required to accomplish it.

Most tool sharpening done in industry is accomplished by holding a tool clamped firmly in a jig or fixture which can be traversed and adjusted with hand wheels and whose bed or table is very often actuated by power. The tool is held in such a position that there is an even sharpening along its entire length or if it has several cutting edges, as a metal milling cutter, it is adjusted so that each edge receives the same treatment as far as cutting angle, clearance angle, rakes, etc., are concerned. This type of exact sharpening is necessary in industry to maintain the uniformity of the product and a high rate of output.

Industry is constantly conducting research to discover better clearance angles, rakes, and reliefs for production tools. Whereas it might be impractical for students to experiment very much in this manner, it would be invaluable to them to develop a concept of the purpose of each of these aspects of the cutting tool and how they are produced. More specifically in regard to the importance of clearance, Covell has this to say:

> The proper clearance behind the cutting edge of the tool is essential. Too little clearance will cause the heel of the tooth to drag over the work, resulting in

> friction and slow cutting; too much clearance will produce excessive wear and chatter. Deviation from the ideal, if any, is less objectionable on the side of too much rather than too little clearance.[1]

The offhand or freehand grinding of tools was by far the most common maintenance activity encountered in industrial arts shops, but very few sharpening gauges were seen. Plane blade sharpening attachments and twist drill sharpening jigs would seem well worth their cost in promoting an additional asset, that of helping to develop concepts of the cutting edge. Larger schools should no doubt purchase saw filing machines and precision tool-room grinders for the same reasons.

Concepts Related to Specific Tools Which Have A Cutting Edge

The concepts related to all cutting edges will develop through perceptions experienced with many kinds of cutting edges in many kinds of situations. Full understanding develops slowly and even experienced workers can broaden and deepen such concepts with new experiences and perceptions of the cutting edge and the cutting process. For the student in the industrial arts shop the concepts related to all cutting edges will develop through contacts with the tools in the shop.

Accordingly, this section includes the concepts related to specific tools that may be used in the school

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[1]Covell Manufacturing Co., Operators Instruction Manual (Benton Harbor, Michigan: Covell Manufacturing Co., 1944), p. 22.

industrial arts shop and indicates how these may contribute to the development of the concept of the cutting edge and may also serve to bind together several areas of the industrial arts shop. The tools will be considered in the following order:

1. The knife
2. The chisel
3. The plane
4. The drill
5. The saw
6. The file
7. Abrasive cutting tools

In each case the arrangement of the cutting edge, the modifications between wood and metal working tools, industrial variations, and possible approaches by the teacher will be considered.

The Knife

Probably the first cutting edge with which an individual becomes familiar is the knife. As a pocket knife, kitchen knife, or table knife, it enters daily life early and often. Nevertheless, the industrial arts student may not have an understanding of the functioning of the knife and its cutting edge which can be transferred to the understanding of other cutting edges. Because of its commonness and familiarity to most people the development of a concept of the cutting edge might well begin with the ordinary pocket knife.

The knife resembles a wedge; therefore, it was a heavy back and a thin cutting edge. The slope between the back and the edge is the cutting angle. For most knives this is a rather small angle. The pocket knife is a useful tool to a carpenter. However, the cutting edges of some industrial machines for shaping wood and metal are in reality knife-like edges. The milling machine cutter has a series of cutting edges, and each is in effect a specialized knife.

Most students have done wood whittling. This may be a point at which the teacher can start the development of an understanding of the cutting edge, for one of the earliest percepts made by pupils is whether the edge of an ordinary knife is dull or sharp. On the other hand, few students realize how this reduced surface (the edge) can with hand power exert the tremendous pressure necessary to make the initial nick and then to wedge the chip or shaving clear. The mechanical advantage of such an edge has, of course, been perceived since ancient times, tools and weapons being pointed as an aid to penetration.

Once the knife or other tool has made the first nick, the bevel or taper from the edge to the full thickness of the blade acts as a wedge to break the excess material from the main section of the wood. The depth of the cut must not be so great as to give such strength to the chip or shaving that it will resist curling and breaking clean. If the chip or shaving is too large, the wood may split. This is one of the basic understandings in the use of knife-like tools of which students are often unaware.

Cutting any organic material is, in the final analysis, essentially a process of separating a cell, or part of a cell, from the remainder of that cell or from other cells. The ease with which this can be done depends upon a number of factors, such as the toughness of the cell walls, the keenness of the edge, the force available to drive the edge, the contents of the cells, the speed with which the force is applied, and the elasticity of the total material. However, cutting any organic material, as wood or leather, requires less force than does cutting materials such as metals or ceramics.

Holding the work so that the tool can function best is also an important phase of using a knife. E. L. Palmer[1] points out how an experienced whittler continually shifts or rotates the work so that the knife edge is always attacking a corner, thus allowing the sharpened edge of the knife to easily bite into the reduced surface of the corner. Sliding the knife at a modified slicing angle is also helpful in achieving an easy cut.

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[1]W. A. Thurber and E. L. Palmer, "Common Hand Tools," Cornell Rural School Leaflet (Ithaca, New York: Extension Division, College of Agriculture, Cornell University, March, 1944), Vol. 37, No. 4, p. 261

As the student gains understanding of the knife edge as it is applied to wood, he will also be turning to the use of other materials and applying cutting edges to them. In each, the teacher should no doubt point out the similarities but also the differences that are met in both the tool and the material.

When the cutting tool is applied to the harder metals, there must be design changes because of the change in hardness of the material. Great pressures are now involved between the edge and the steel. The abrasive stresses and forces caused by minute vibrations require, commercially, a material far more durable than carbon steel.

The understanding of how a woodworking tool edge makes the initial nick and then rolls a shaving free of the work by cutting across organic cell structure must be altered and broadened. Machine steel is crystalline and not organically cellular. A number of engineering departments have been working on industrial machining processes where, by stroboscopic representation, they show that the edge of a compressed-carbide steel lathe tool seldom actually touches the work after the initial nick has been made. As a matter of fact, these experiments indicate that some waste metal removed from the work in the process of machining adheres firmly to the surface of the tool so that this built-up edge takes the brunt of the activity of machining. At first impression students find this idea difficult to accept.

Concerning the cutting of metal Doyle points out both the mechanism of chip formation and the built-up edge in the following:

> When a tool cuts metal, it is driven by a force necessary to overcome friction and the forces that hold the metal together. The metal that the tool first meets is compressed and caused to flow up the face of the tool. The pressure against the face of the tool and the friction force opposing the metal flow build up to large amounts. . . . The stress in the material ahead of the advancing tool reaches a maximum in a plane approximately perpendicular to the tool face. That plane is known as the <u>shear plane</u>, . . . When the strength of the metal is exceeded, rupture or slippage occurs along the shear plane. With further movement, new material is compressed by the tool, and the cycle is repeated again and again. As it travels along, the cutting edge scrapes and helps clean the surface.
>
> When steel is cut, a continuous chip is formed, but the pressure against the tool is high, and the severe action of the chip quickly rubs the natural film from the face of the tool. The freshly cut chip and the newly exposed material on the face of the tool have an affinity for each other, and a layer of highly compressed material adheres to the face of the tool. . . . and is called the built-up edge.
>
> Metal cutting is cyclic. The cutting force builds up to cast off a chip segment or cause slip in a shear plane. Then momentarily the force may drop off while the tool is taking another bite, and the cycle is repeated. These changes occur at high frequencies. . . .[1]

As the student meets each new cutting tool, he should be encouraged to examine it to understand how it functions. To appreciate that a certain metal cutting tool acts in the same manner as a knife may cause the student to more quickly gain skill in using the tool because he realizes how it should be held and handled. He will also realize the

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[1]Lawrence E. Doyle, <u>Metal Machining</u> (New York: Prentice Hall, Inc., 1953), pp. 57, 59, 62.

necessity for properly gauging the depth of the cut. Industry makes much use of this type of cutting edge.

The Chisel

A chisel is another cutting edge with which students are apt to be familiar by the time that they reach the industrial arts shop. Nonetheless they may not realize how chisels are built to work and may use them for all sorts of jobs for which they are not designed. A chisel is a tool for cutting away unwanted material or for manual cutting in special situations. It is a piece of tool steel ground to a bevel at one end with the bevel sharpened to a cutting edge. The sides are usually straight or sometimes beveled but not sharpened, and a handle is usually present. In the case of a woodworking chisel one side is flat which makes it different in shape from the knife. The chisel is by shape a true wedge. Some chisels for metal, the so-called "cold chisels," are made from octagonal stock and beveled on two sides to a point somewhat like a knife but with a much larger cutting angle, hence, the edge is less keen.

A chisel for woodworking may perform many of the same functions that a knife does, but being a heavier tool with a stronger blade it may do heavier cutting. When used for paring along the grain it may be used to make a heavy or roughing cut to remove unwanted wood, particularly when the cut is a notch, or to make a convex or a concave curve. A chisel is used to cut across the grain in making mortises, grooved joints, and lap joints. A chisel may be used to make vertical cuts--cuts at right angles to the surface of the wood--as for a mortise, a space for a hinge, or in rounding the corners of a board. In each of these uses, the chisel functions because it has a keen cutting surface that can start the shavings and wedge them loose and also because it is sturdy enough to be used with the necessary force. In vertical chiselling a mallet is often used to supply the force for the work. For each type of work with the chisel there is a proper way to hold and use the tool. As students have occasion to learn these activities they should be shown the correct method for using the tool, but at the same time the teacher should call attention to the way that the cutting edge operates and why the method suggested is the most efficient and effective.

The effect of the bevel of a chisel indicates which way the tool should be applied to preserve the desired wood and to break-up and remove the waste. Further in this connection, Hjorth points out:

> When making a heavy or roughing cut, the chisel is used with the bevel side down. . . . Chiseling always should be done <u>with</u> the grain. When chiseling against the grain the cut cannot be controlled because the chisel will follow the direction of the wood fibers. . . . (for smoothing cuts--) The chisel is now reversed so that its beveled side is up. . . . If the edge is held diagonally to the direction of the cut, the chisel will do its work more easily and with less danger of "digging in" . . . By vertical chiseling is understood cutting at right angles to the surface of the wood,

> usually across the fibers. . . . Most vertical chiseling consists in making first a perpendicular cut and then a slanting cut joining the first. The bevel of the chisel is always held toward the waste side of the cut.[1]

A gouge is another woodworking tool with which the students may make an acquaintance. As far as the cutting edge and technique is concerned, the gouge is a chisel whose cutting edge has been curved lengthwise. The bevel may be either on the inside or the outside of the tool. The amount of curvature varies as does the width. Gouges are used, for instance, to cut grooves. Handling gouges requires much the same technique as handling chisels. As the students use these tools, their similarity to the chisel should be called to their attention and a further understanding of the cutting edge developed.

An understanding of this type of edge and its use has additional importance because many power woodworking tools use a chisel-like cutting edge. Examination will reveal that some tools for a wood-turning lathe are like a chisel at the cutting edge.

The concept of the change in character of a tool from one for woodwork to one for metal-work is characterized by the cold chisel. It usually is beveled on both sides of the blade with a much steeper bevel and hence a larger cutting angle to resist breakage and deformation from strong hammer blows. Olson defines it in these words: "A cold

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[1]Hjorth, op. cit., pp. 84-88.

chisel is a hardened piece of tool steel with the cutting edge sharpened as a wedge and the other end blunt to receive hammer blows."[1]

The chisel for cutting metal is used for much the same techniques on metal that chisels perform on wood. Wagener and Arthur summarize the types of metal-working chisels, together with the uses and techniques of using each, as follows:

> The cutting edge of the chisel should be held at the point where the chipping is to be done, at an angle that will produce the desired depth of cut, and so that it will cut in the direction desired. The depth of the cut will depend on the angle between the centerline of the chisel and the work; the greater the angle the deeper the cut. As the chisel approaches the edge of the work, if the cut is very heavy, it should be directed at a right angle to the former direction of cutting action.
>
> The "cape" chisel. . . . is used for cutting narrow slots, rectangular grooves, and keyways.
>
> A diamond-point chisel is used for chipping V-shaped oil grooves or for making sharp corners in holes that are square or rectangular. . . . it is frequently used for chipping a groove in the conical-shaped depression formed by a drill, or for drawing the drill back on center.
>
> The round-nosed chisel is used for producing a concave surface. . . .
>
> To produce an even or flat surface with a chisel it is necessary to hold it at a constant angle of inclination to the work and keep the cutting edge against the shoulder formed by previous blows of the hammer.[2]

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[1]Delmar Olson, Industrial Arts for the General Shop (New York: Prentice-Hall, Inc., 1955), p. 107.

[2]Albert M. Wagener and Harlan R. Arthur, Machine Shop Theory and Practice (New York: D. Van Nostrand Company, Inc., 1950), pp. 248-49.

According to this information, it is seen that the character of the chisel changes with the material that it cuts; at the same time the type of cutting that is done by a chisel is essentially the same in both wood and metal. As the student has occasion to use the chisel in any material, he should be aware of how it works and the reasons for handling it as he does. He should also be aware that each kind of chisel has its special use and should be encouraged not to misuse the tool by trying it for uses for which it was not designed.

The Plane

The plane, basically consisting of a chisel-like cutting member mounted in a frame for support and control, is a tool more often used for wood than for other types of materials. The hand plane will probably be familiar to most students, although, once again, the skill in its use or the understanding of its functioning as a cutting edge will often be lacking.

The plane is particularly exemplary as a keen edge supported by the mechanism in which it is mounted. Allowing the plane iron to protrude too far brings to the students' attention the tendency of the blade to follow the grain and to upset the intended travel of the plane. The use of the plane-iron cap on the plane-iron in the plane assembly is an example of an attempt to give the advantage to the tool and to take it away from the work. Actually this is the basic purpose in the design of all tools and is particularly well exemplified in cutting tools.

The matter of stance in operating a hand plane and the movements of the body are the usual first perceptions of the industrial arts student, who then imitates the instructor. Actually the manner in which the plane iron cuts into the wood and rolls up a shaving is the crux of the process and should be a determiner of both the stance and the effort. Insight into the shape and character of the plane iron, the keenness of the edge, and the manner in which it cuts most effectively within the limits of hand power can cause understanding to be favored over ordinary repetitive training, particularly in view of the ordinary limits of the school time-budget. In some cases, repetitive training with much practice should probably not be altogether minimized, particularly when the vocational or terminal aspects of some public school responsibilities are concerned. Nevertheless, efficiency and progress demand that understanding be a dominant goal when the over-all aims of general education are being explored.

Fryklund, well acquainted with the need for realism, describes the technique of planing:

> When starting the stroke bear down on the knob at the front end of the plane. When the plane is well on the board, bear down equally on both the knob and the handle. As the plane begins to pass off the board

relieve pressure on the knob.[1]

If the student realizes that the cutting edge of the plane is a chisel which is slicing a shaving loose from the wood, it will be more obvious why it is necessary to maintain an even pressure by following such instructions as the plane traverses the board.

Woodwork hand tools, in addition to the design principles of their edge and the functions of their hand grips, require a concept of the grain of wood. The cutting edge must be supported and must be restrained from choosing just the easiest path through the wood, which is usually along the grain, when this is contrary to the dimensions laid out. When the effect of the tool is one of wedging or splitting along the grain in an undesirable manner, considerations other than the force applied to the tool must enter in.

Some basic concepts about woodworking tools seem to go on for years with few changes. For example, in 1927 The Stanley Rule and Level Company said:

> . . . A short wood plane follows the shape of the wood as a small boat rides over the waves and into the hollows in between. A longer plane does not follow the hollows.[2]

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[1]V. C. Fryklund and J. A. LaBerge, General Shop Bench Woodworking (Bloomington, Ill.: McKnight & McKnight Publishing Co., 1955), p. 23.

[2]The Stanley Rule and Level Company, How to Work with Tools and Wood (New Britain, Conn.: 1927), p. 43.

> . . . Planing against the grain roughs the wood like stroking a cat's fur the wrong way. Planing with the grain leaves the wood sleek and smooth.[1]

In most industrial work with smoothing of a wood surface, such as that which the plane accomplishes, is done with power machinery. With plywood and many of the newer forms of wood, planing is often unnecessary because the surfaces have already been smooth.

For hand smoothing of a metal surface the file functions in place of the plane for wood. However, power-driven metal planers are used in some types of machine production. The student in the industrial arts shop can gain an insight into how the smoothing is done with a plane or file by the work that he may do with the hand tools or with the machines that are available in the shop. He then can appreciate the problems that industry faces in doing the same processes on a large scale.

A surface smoother than that produced with a plane is usually obtained by using a scraper or by using abrasive cloth or abrasive paper which may be actuated by hand or by a machine.

The Drill

Round holes in a material are required in industry to permit the installing of fasteners and components and to provide passageway for materials such as lubricants, to

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[1] Ibid., p. 11.

provide ventilation, for valve installation, and so on. Because of the economy of time and the accuracy obtainable, necessary holes are punched wherever it is feasible to use a punch. In situations where punching is not possible drilling becomes a favored way of making holes.

The end of a drill is essentially a specialized cutting edge and is useful in concept development. The relative hardness of drill and material again largely determine its shape and application. The wood auger bit has an essentially knife and chisel type of edges, with a wood screw type point to help draw the auger through the wood and also has a spiral shank to draw the chips out of the hole as the auger progresses through the wood.

With the present-day popularity of portable electrically-driven tools, the electric drill is by far overshadowing the auger, brace and bit for most purposes. Holes may now be drilled cleanly and rapidly in wood with an alloy steel drill bit which is essentially a nonadjustable fly cutter composed of two chisel-shaped lips and a point which guides the tool through the wood.

Most holes in metal are drilled with a twist drill possessing two cutting lips slanted upwards to form a point at the center. The cutting edge at the lips is formed by grinding a clearance angle of about 12 to 15 degrees, for general purposes, and the cutting edges are slanted to form an apex in the center of the drill with each lip making an angle of 59 degrees (again for general purposes) from the center line of the drill.

The concept of the cutting edge can be reviewed to show how the edges are placed to cut when given a rotary motion and how the junction in the center forms a pivot about which the drill revolves. This pivot permits the drill to be positioned in a center punch mark to begin its cut. It can be shown that the very point of the drill must actually wear through the material being drilled because of the thickness of the web of the drill. The teacher can show how a notched, crankshaft, or split lip drill has the lip's ground differently so that the web need not wear through the material. Such a drill cannot be started in a center punch mark but must be guided by a drill jig or fixture because of the lack of a point.

A split lip drill is, therefore, useful for concept development and for showing the student some aspect of mass production in which a number of holes in a component must be positioned accurately and drilled quickly. Simultaneous or multiple spindle drilling seems much less adaptable to the industrial arts shop. It would seem better to have a few kinds of drills operating correctly than to try to duplicate the many specialized drills used by industry. Colvin and Stanley point out in this connection:

> Nine kinds of drill points are in common use. . . . All have been developed for a purpose. . . . A point angle of 118 degrees included, or 59 degrees on a side,

has been standardized for general work.[1]

There is probably no sounder a source for these concepts than the industrial companies whose very future depends upon the results obtained by their customers. One of these companies, Chicago Latrobe, has gone on record in this connection:

> A twist drill has three main divisions - point, body and shank. The point is the cone-shaped end which does the cutting. The body is the section between the point and the shank and has two grooves known as the flutes. . . . the point of the drill has many construction features which must be carefully formed in relation to each other in order that the drill will cut efficiently and to size. The sharp edge at the extreme tip of the point is known as the chisel edge.[2]

Chicago Latrobe in this case exemplifies an attempt of private industry to isolate those fundamental concepts involved in the industrial application of their product and then to go all-out to implement such concepts in the realistic world of industrial work.

The Saw

The saw is another tool that most students will know before they reach the industrial arts shop. But, as with the other familiar cutting tools, few of them will understand the basic principles of how the saw cuts and its construction.

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[1]Fred H. Colvin and Frank H. Stanley, American Machinists Handbook (New York: McGraw-Hill Book Co., 1945), p. 125.

[2]Chicago Latrobe, Catalog No. 51 (Chicago, Ill.: Chicago Latrobe Co., 1953), p. 114.

If they have skill in using the saw, it will usually have been acquired through imitation, not through complete understanding of the way the saw functions.

A knowledge of the action of the teeth of a saw is helpful in knowing its use. Indeed, Fryklund and LaBerge devote considerable space to such topics. For example, they write:

> . . . Saw teeth are coarse or fine according to their size. This is determined by the number of points per inch. There is one more point to an inch than there are teeth. Crosscut saw teeth range from 6 to 12 points per inch, and ripsaw teeth from 4 to 7 points per inch. . . . Even though a crosscut tooth is like a knife, its cut is unlike that of a single knife edge. When the saw is in motion, the forward edges of the teeth cut the fibers, making two small furrows with a ridge between them. This ridge is gradually crumpled by friction while at the same time a new one is being formed as the furrows go deeper and deeper into the wood. . . . Ripsaw teeth are like two parallel rows of small chisels. At each forward of the saw the edge of each little chisel cuts the end off the wood fibers. Each tooth as it follows the other cuts more fibers until finally the board is ripped.[1]

The crosscut saw, as its name implies, is used to cut across the grain of the wood. The ripsaw could be misused to cut across the grain, but because its teeth are like vertical chisels the cut will probably be very rough. The ripsaw teeth function best when used to cut along the grain.

Students should be encouraged to examine carefully the teeth on each type of saw that they have occasion to use. The difference in the shape and slant of the teeth between a

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[1]Fryklund and LaBerge, op. cit., p. 101.

crosscut saw and a ripsaw should become obvious. Further, it should also become obvious that the hand saw will cut only on the forward stroke. Realization should follow that sawing cannot be done too rapidly because the teeth must have time to work and to clear away the sawdust. This examination should also reveal that to cut effectively the hand saw must be held so that the teeth meet the wood at the most effective cutting angle. The realization of these facts will make the student use the saw more efficiently because of understanding, not because of imitation.

Observation of the saw teeth will also reveal that not all the teeth are in a straight row but that each tooth is turned slightly out so that the total cutting edge is slightly wider than the saw. The space left when the saw makes a cut is known as the saw kerf. The kerf is slightly wider than the saw to reduce it binding against the side of the cut. The angle of the teeth to each side is known as the set of the saw. In sharpening or reconditioning a saw it is necessary to reset the teeth.

Maintenance of hand saws requires an understanding of the cutting edges so that skillful filing and setting can restore their efficiency. Shea and Wenger describe the process in these words:

> A saw that has been used over an extended period of time and as a result has become dull and worn, should first be jointed. This term means that the tips of the teeth must be leveled off so as to provide an absolutely straight cutting edge. A file or flat emery stone is

> then rubbed across the points of the teeth. . . . When the blade has been properly jointed each tooth is filed to a uniform shape. . . . Before the saw teeth have been properly filed, it is necessary to set each tooth so that it staggers or bends in an opposite direction to its neighbor. This set is obtained by using a tool which resembles a pair of pliers called a saw set. . . . The teeth of a saw are set to clear the blade and prevent it from binding. It is interesting to note that soft and wet woods require more set to cut them properly than hard and dry woods. . . . Teeth of a rip-saw are sharpened by filing straight across the blade. Teeth of a crosscut saw are sharpened with the file held level but on a 60° filing angle.[1]

The hand saw of the woodworking shop may not find wide use in industry at the present time because of the extensive use of machines in place of hand tools. But the basic concept of the saw, its structure and functioning, applies to the various power saws that are used for industrial wood work.

Many of the concepts of the saw with respect to wood can be applied to metal work if the crystalline structure and increased toughness of metal is taken into consideration. A vital difference in working with metal involves an appreciation of how much harder metal is than most woods. The rate at which most metals can be cut is drastically less than the rate at which common woods can be cut.

The hand saw for metal is known as the hacksaw. If the student understands the structure and functioning of the saws for wood, it is easy to develop the understanding of how

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[1] J. G. Shea and P. N. Wenger, Woodworking for Everybody (Scranton, Pa.: International Textbook Co., 1947), p. 110.

the hacksaw differs. A hacksaw usually has finer teeth than a saw for wood, and a good rule-of-thumb is to make sure at least three teeth of a hacksaw blade rest on the work at all times to prevent teeth breaking off. The concept of relative hardness here again comes in for review. The hacksaw blade is not nearly as much harder than the steel it cuts as a steel saw for wood is harder than the wood.

The teeth of a hacksaw can either be set (staggered to each side) as in a saw for wood or the teeth can describe a wavy line to provide clearance for the blade. "A saw that is properly set will produce a saw kerf wider than the thickness of the blade and prevent the saw from binding."[1]

When using a hacksaw, the concepts of friction-heat ought to cause the pupil to reduce his number of strokes per minute so that he will not overheat the teeth to the point where they lose their hardness and hence cease to cut. To some extent this same understanding applies to sawing wood. However, because the friction is much less, the danger of overheating is commensurate.

In industry metal is often cut by other means than with a saw. Friction cutting with a metal-cutting bandsaw on first approach seems to belie previous conceptions inasmuch as the teeth of the bandsaw blade are sometimes blunted rather than sharpened for special purposes. The blade may

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[1]Fryklund and LaBerge, op. cit., p. 49.

cut refractory materials, for instance, whose constituents are harder than the blade itself. Smith describes what occurs in this type of cutting:

> Most conventional methods of cutting metals employ a cutter with a keen edge. When cutting by friction a keen edge is not required; in fact a dull edge is the more effective tool, because the dull instrument creates more friction and consequently more heat. . . . This softens the metal immediately ahead of the blade and thus increases cutting efficiency.[1]

Metal may also be cut with intense heat which will melt the connecting metal or may even completely oxidize it. This type of cutting can be demonstrated with oxyacetylene welding equipment.

The File

Many students will already be familiar with a file for use either with wood or with metal. Probably they will associate it more with sharpening tools or filing metal than for use on wood. It is probable that the student will not think of the file as a cutting edge, although he has used it to remove excess material. To the student there will probably seem to be no edge. The teacher will need to call attention to the fact that each of the teeth on the surface of the file acts as a cutting edge, or as a tooth for cutting. The file, then, will not remove large amounts of material at one stroke but will make a series of cuts on the material.

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[1] R. E. Smith, Machining of Metal (Bloomington, Ill.: McKnight & McKnight, 1949), p. 163.

The fineness of the teeth will, of course, determine the fineness of the cuts and the amount of smoothing of the surface that the file may do. Examination under magnification may help the student see that each tooth is a cutter.

Files do not find as wide use in the woodworking shops as they do in the work with metals. According to Haines,

> The wood file is used to smooth edges and curves that are difficult to smooth with other tools. The cutting surface consists of sharp edged ridges or teeth. The cut of the file is determined by the spacing between the teeth and the angle at which the teeth cross the surface of the file.[1]

The rasp resembles a file and is used in much the same manner but the surface is covered with semi-circular points or teeth. Each point is a separate projection, not a member of a series in the same sense as with the file. Again, magnification will help this perception.

Barnwell considers the file one of the most important of the hand tools for use with metals and one of the more difficult ones to learn to use with skill. He describes the types of files and the techniques of using a file and then suggests:

> Files, like all other tools, should be handled carefully, since their useful life may be greatly prolonged by correct use. . . .
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> The correct order in which a new file should be used is important. Thus, if it is used on, say copper,

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[1]Ray E. Haines, Woodworking (New York: D. Van Nostrand Company, Inc., 1945), p. 35.

> aluminum, zinc, brass, wrought iron, and mild steel, in that order, its life will be far longer than if the new teeth were dulled by using it on the harder metals first.[1]

A metal cutting file, like the wood cutting file, is really a series of teeth arranged on a blade so that each tooth has only a light slicing cut to make. The teeth of some files are so similar to, but not as large as, the teeth on metal-cutting milling machine cutters that some workmen refer to a file as a "handmill." Fryklund and LaBerge describe the kinds of files:

> The cut of a file refers to the parallel series of teeth on the file. For example, single cut files have parallel lines of teeth running diagonally across the file face. When there is a double series of teeth crossing each other at an oblique angle, the file is said to be double cut. . . . The cut of files is divided with reference to the character of the teeth, into single, double, rasp, and curved; and with reference to the coarseness of the teeth into rough, coarse, bastard, second cut, smooth, and dead smooth. Single cut files are used . . . to produce a smooth surface finish . . . double cut files . . . are used for fast metal removal. The rasp consists of a series of individual teeth produced by a sharp, narrow, punch-like cutting chisel. . . . It is used principally on wood . . . aluminum and other soft substances for fast removal of material.[2]

The shape and fineness of the file determine the rate at which it will cut, provided it is fitted for the hardness of what is being cut. As a matter of fact, some workmen use a file to discover the degree to which heat-

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[1]George W. Barnwell, The New Encyclopedia of Machine Shop Practice (New York: Wm. H. Wise & Co., Inc., 1941), p. 5.

[2]Fryklund and LaBerge, op. cit., p. 35.

treatment has been given to a piece of metal. Glasshard or not-fileable denotes a case hardening or heat-treat which would need to be altered by annealing, or perhaps the machinist should actually refrain from trying to shape or mill it (with subsequent risk of cutter damage), although he could probably use carbide cutters. Grinding might also be suitable in this case.

In cutting metals a concept of chip clearance is necessary even in using hand tools. Lack of clearance in the shape of a tooth will prevent the edge from biting into the metal. Lack of clearance for the filings at the base of the tooth causes the file to load-up. This is particularly true when soft, tenacious metals permit large teeth, spaced so that the filings can drop out easily, to be employed if desired. Chalk dusted on the file helps prevent filings from sticking to the file. Dirty, sticky files also encourage chips to stick. Rasping wood also runs into this difficulty. To clear the rasp Hjorth suggests that it be dipped in alcohol. The alcohol remaining on the file can be ignited and will burn with a small blue flame, consuming the wood wedged between the teeth. The charred wood can then be brushed out with a file card.[1]

The file may be used to produce a smooth finish on metal in much the same way that sandpaper is used on wood.

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[1]Hjorth, op. cit., Article 2, p. 7.

The final finishing is usually done by the process known as draw-filing. In this technique the file is held so that its principal dimension is perpendicular to the direction of travel. How each tooth of the file produced a slicing cut in draw-filing by virtue of the transverse slant of the teeth is a variation of the filing concept.

The teacher should help the student become familiar with the types of files and their uses. As with the other hand tools used for cutting edges, an appreciation of the tool and the job that it is designed to do should develop as the student makes use of the tools in the shop activities.

Abrasive Cutting

Whereas many of the industrial arts students will have already had experiences with the usual form of a cutting edge and will perhaps realize that these are cutting edges even though they may not understand how they operate, probably most of the students will not think of the use of abrasives--sandpaper, emery cloth, grinding wheels, jewelers rouge, etc.--as a use of a cutting edge. They will not realize that the effect of these materials is the effect of many cutting edges acting in unison.

Two fundamental concepts of cutting edges generally are readily adapted to the use of abrasives. First, the edge doing the cutting must be harder and more durable than the material which is being cut. Secondly, the edge must present a suitable attitude or angle of attack to the work so that relative movement will give the sharp edge of the abrasive crystal a chance to make the usual initial nick and roll up a minute shaving. If these concepts have been developed with the previous cutting edges used, they will be rather readily understood in this situation.

For most purposes natural abrasives such as sandstone have been replaced by new synthetics. However, some natural stones, such as garnet and emery, are still useful abrasives. An effective way to get the crystals (which are far too numerous per square inch to be handled individually) to take the proper angle so that they can be cemented to the paper or cloth backing is to give them an electrical charge and then pass them under an electrode which will polarize them to the extent that they will all stand "on end" to be cemented to the backing. Each crystal or grain will then be in a position to cut a small scratch, groove, or furrow depending upon the size of grain. Various adhesives are used to fasten the mechanically sorted crystals to the backing of paper or cloth so that power can be applied to them to do the cutting.

One common way of separating crushed abrasive grains of various sizes during manufacturing is to sift the grains through screen of different mesh size. The mesh of a screen, or the number of openings in the screen per square inch, is one method used to classify the various size grains by calling them 120 grit, 320 grit, etc. For greater durability the grit is sometimes cemented to durable cloth belts or discs instead of paper, and sometimes a waterproof cement is used so that the abraiding operation can use water to reduce the clogging of the abraided material between the abrasive grains. As with files, such collection of material prevents the cutting edges from making an effective contact with the work.

Power sanders, both disc and belt, are a variation of abrasive cloth in one sense and of grinders in another. Most shop teachers have on occasion found a sander belt so overheated from the friction of sanding that the adhesive was melted, causing the grains of grit to disappear.

Of abrasives in woodwork, Fryklund and LaBerge say conceptually:

> . . . other abrasives are sandpaper, emery cloth, emery dust, pumice stone, and steel wool. The cutting action of an abrasive is similar to that of a plane or scraper. Each little plane shaves off a minute shaving from the surface. Since there are so many grains and all of them are on the same level, they make the surface seem smooth. Grinding stones are usually hard and will grind metal away.[1]

By observing an abraided surface with a magnifier it becomes obvious that sanding or polishing is an operation in which a great multitude of small scratches are made in the surface and in which irregularities in the surface may be reduced to the size of the scratches. Such examination will

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[1]Fryklund and LaBerge, op. cit., p. 102.

also reveal that there is a limit to how smooth a given piece of wood may be made.

Because of the cellular structure of wood it is best not to make these scratches across the grain. This will result in a rather rough, torn and shredded surface. Stains or coloring will naturally seep into these grooves, darkening them more and accenting their presence. Scratches with the grain are far less conspicious. In metals, without this organic cellular structure, it is still in the interests of fine finish to have all observable scratches run as parallel as possible.

By using a finer and finer abrasive, finer and finer scratches result until finally the ability of the eye to resolve such minute detail is exceeded and we say a surface is polished. If too big a jump in size to a finer abrasive is taken, the unsatisfactory situation of polishing up the previous scratches takes place and a poor surface may result. The previous scratches should all be removed by the next smaller abrasive before a yet finer grade is used. In metals, running one set of scratches at right angles (or at least an angle) to the previous coarser ones indicates the time when the next finer grade can be applied. There are very, very fine crystals in a piece of crocus cloth, but even finer scratches still can be made by driving the millions of small crystals found in jewelers rouge against the surface with a fabric buffing wheel. Many so-called polishes contain these minute abraiding crystals in paste or liquid form.

Attempts are made commercially in some non-scratch polishes to dissolve chemically an unattractive film on the work, or to use an abrasive soft enough to scratch off the dirt but not hard enough to be too destructive to the base finish. Polishing articles made of gold in a "shake-bag" of sawdust is a good example of this, but even jewelers save their particles of polishes so that abraided gold particles can be reclaimed and sold.

A concept which must never be forgotten is that an increase in force will drive any cutting edge, including abraiding crystals deeper and deeper, probably more than intended. Therefore it is essential to maintain a uniform pressure if a spotty surface is not to result. Progressively abraiding a metal surface with finer and finer abrasives and finally entering a lapping process produces surfaces so flat and true that gauge blocks accurate to three millionths of an inch can be produced and so flat that they can be made to stick together with a firmness that great pressure is required to separate them because of molecular cohesion and vacuum.

Another understanding of abraiding can be developed by means of the grinding wheel. Instead of cement, a bond of ceramic, resin, or rubber is often used to hold each crystal or grain so that it can make its scratch as it is driven across the work. The grains and bond are molded together in manufacture to give the grinding wheel its shape and firmness.

Grinding wheels vary a great deal as to kind of grit, size of grit, kind of bond and optimum R. P. M. Wheels with a less tenacious bond which can be worn to expose new crystals easily are called soft wheels; conversely, hard wheels have a tough bond. Green wheels are very hard. Bonds can be produced which are vitrified or glass-like and hence brittle and easily disturbed, or the bond can be tough and flexible so that a very thin wheel can be used to cut off steel rapidly or to cut refractory, and other very hard materials.

In the process of use it is obvious that even the edge of a very hard crystal may become broken off or dulled. Inasmuch as grinding wheels are made of much the same constituents almost the total distance to their centers, it becomes clear that if old crystals are cleared from the bond and new ones exposed, the grinding wheel would in effect have been sharpened.

Restoring the surface of the grinding wheel is known as "dressing" the wheel. Two methods are commonly used. First, grinding wheels can be trued and dressed with a material harder than the wheels, commonly a commercial black diamond, held in a suitable holder. Attention might be called here, again, to the general concept that a cutting edge must be harder than the material. Secondly, if a large number of light blows are struck on the surface of a grinding wheel, some bond can be crumbled to expose the yet unused crystals (grit) underneath. This is commonly done by holding the wheels of a wheel-type dresser against the grinding wheel as it is revolving. These blows should never be allowed to reach proportions which would fracture the entire wheel itself.

The knowledge that there is a bond which is designed to fracture between the outermost crystals or grit should alert the student to the fact that the grinding wheel is bound to change its shape as it reacts with what is being ground. As one would expect, grinding wheels are engineered so that there is an optimum velocity for a crystal to cross the work. If the wheel is reduced too much in diameter by wear or repeated dressings it is obvious that the now smaller circumference of the grinding wheel will drive the crystals in its periphery at lower and lower velocities (in surface feet per minute) and the efficiency will be reduced unless spindle R. P. M. can be increased commensurately.

In many vitrified grinding wheels, there are small pores or spaces between the bond and the abrasive grains. As with files these rough pores become filled or loaded easily with tenacious materials such as copper and aluminum. The pores can fill up so much that the grit can scarcely protrude to do any grinding. Special grinding wheels are needed for such tenacious materials. This same concept, of course, holds true for abrasive cloths and papers. It is called "structure."

Some tool-grinding wheels are of fine grit, and care must be taken so that the heat of grinding does not change the crystalline structure of the steel. To prevent this unwanted change, some wheels are cup-shaped so that an oil may be dribbled on the inside of the cup and then centrifugal force will carry it through the pores to the outer circumference where the tool makes grinding contact. This oil both reduces loading and helps cool the tool. Grinding is often expedited by using a fluid such as water or oil which performs functions of cooling and preventing loading. It is necessary for the grit to be able to protrude through this film, which in the case of some oils is difficult.

The concept of hollow-grinding is valuable to anyone who uses edged tools. The diameter of the grinding wheel is a determiner of how much curvature the bevel of the edge will take, and the angle of the tool rest helps determine the total shape of the slope of the bevel and hence possibilities of keenness.

The concept that centrifugal force stresses upon a grinding wheel should cause a pupil to check the maximum safe R. P. M. of a wheel he may be installing against the spindle speed of the grinder. Errors of over-speeding can be dangerous, and under-speeding causes poor efficiency.

If each grain of abrasive in a grinding wheel takes one light cut on the work per revolution, each of the other innumerable grains of grit does likewise. If one were to count the number of grains and multiply this by the R. P. M.

the number of cuts per minute would be fantastic. A concept is here in the making. When a lathe with a single cutter exerts its tremendous force upon the rotating work it is inevitable that the work must bow or bend somewhat, depending upon its length and diameter. Inaccurate work can result to the extent of the bow. The drag of the tool must also apply a torsional or twisting stress to distort the work still more. The grinder with its possible light pressure reduces these distortions and millions of cutters (instead of one) result in a far superior (and quicker) surface finish.

Perhaps one of the most far-reaching techniques expediting mass-production, with its need for selective interchangeability of machine parts, is that of centerless grinding, where a cylindrical part is ground to very close tolerances by lightly grinding its surface while the part itself is rotating between the grinding wheel and a control wheel which is also rotating. "Superfinish" is a grinding process in which the grinder rotates and oscillates as the work rotates producing amazingly accurate bearing surfaces and correspondingly close tolerances between shaft and journal.

In the industrial arts shop the student will probably first meet some type of abrasive cutting in the sanding of wood. If the concept is begun with this experience, the teacher will later have opportunities to develop the concept further as the student uses other abrasives. Such understanding applied to the sanding of the wood will help the student to realize why it is so necessary to use abrasives of decreasing sizes. He will also begin to be more able to judge for himself when the size or grade of abrasive should be changed. If power sanders are available in the shop, he will use them more intelligently if he understands the basic concept of abrasive cutting.

In the woodworking industry sanding is now usually done with power tools even on small jobs. In large wood using industries the wood is often sanded with power machinery even before it is shaped and fastened. It is easier to sand a flat unit than an assembled composit. In furniture, then, only a light finishing sanding is needed before the finish can be applied. In very fine custom furniture the sanding and the finishing also is still largely done by hand.

The grinding wheel, if familiar to the students, will usually be so familiar because of its use for the sharpening of tools. Industry does, of course, use them for this purpose. However, industrial uses extend much beyond this use to the application of abrasive cutting of metals by the grinding wheel in place of other types of cutting edges such as the milling machine cutter. For the harder metals the use of the grinding wheel is much more effective than the use of other cutters. This use may not always be feasible to demonstrate in the industrial arts shop. However, if the student understands the grinding wheel as applied to the sharpening of tools, he will be able to understand how it could be used for other shaping of metals.

Summary

In this chapter concepts related to the cutting edge have been developed. This was the concept that was used in the structured interviews with teachers to illustrate the use of a concept to (1) tie several areas of industrial arts together and to (2) illustrate the concept approach to teaching in the industrial arts shop. Many activities relating to the use of cutting edges were observed in the schools visited, but often little attempt was being made to insure that the students were developing any understanding of the cutting process and the cutting edges involved.

Three concepts that seem to apply to all cutting edges have been discussed: (1) the concept of the relationship between the material of the cutting edge and the material to be cut; (2) the concept of the need for and proper type of support for the cutting edge; and (3) the concept of the maintenance of the edge for effective use. All these seem to apply to any cutting edge in any form, made of any material for use on any type of material. The details vary in each case, but the student may develop the concepts by the recognition of these variations.

Some tools in common industrial use apply cutting edges to material, especially wood and metal are: (1) the knife, or knife-like edge, (2) the chisel, (3) the plane,

(4) the drill, (5) the saw, (6) the file, and (7) the means of applying abrasives for cutting. Each of the tools is designed to serve certain functions, or to accomplish certain types of cutting. The recognition on the part of the student of the manner in which the edge is built to serve the function for which it was designed helps the student develop respect for the tools and learn to use them correctly. By means of contacts with and understanding of the tools that he uses, the student gets perceptions and conceptions that develop into the total concept of the cutting edge.

In industry the proportional use of the hand tools as cutting edges is limited. However, the student can best study the edge and perceive the variations and modifications required in the hand tools because usually these are simpler in design. If he understands these tools, he is in a position to recognize the same edges and principles in the more complex forms of the industrial machines.

CHAPTER V

CONCEPTS IN THE WOOD AREA

Concepts Related to the Structure of Wood

The way wood is utilized and treated in a woodworking shop depends largely upon the structure of the material. (1) Knowledge of the cellular structure of wood and its relation to the grain, (2) the cutting to show grain, (3) the luster, (4) the cleavability, and (5) the moisture absorption characteristics which will make more intelligent the use of a particular wood or the substitution of one wood for another. All of these are concepts that a wood-using industry must consider. Their understanding by the student will help him to understand why industry of one type uses a specific wood or why wood-using industries must use certain processes.

Concepts from the wood area are included in this study because woodworking with dressed lumber was by far the most common industrial arts activity found in the schools visited. Only one school was not having students fabricate pieces of furniture from dressed lumber. In each of the other cases hand-tool work predominated on the projects with some of the gross work done by machines. Activities with wood and their resulting concepts seem particularly adaptable to pupils of high school age. Pupil interest in wood-shop activities is clearly one of the main reasons for its popularity as an industrial arts area. Indeed, pupil motivation in this area seems almost automatic. This may be because wood is a medium successfully responsive to rather rudimentary pupil skill and effort with tools.

Ivy, whose writings have been well supported by subsequent investigations, points out some of the need for recognizing concepts in the area and for making the effort to help the learner become aware of these:

> The area of woodworking has been highly developed, but the knowledge acquired has been handed down from father to son and from superintendent to foreman so that much of it has never been printed in such a form as to be readily obtainable. A manufacturer of shuttles knows that they are made of dogwood and persimmon and the manufacturer of school desks knows that they are made of maple, but neither of them has ever seen this in print, and it would probably be difficult to find where this information is recorded.
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> There are thousands of articles made of wood and there are many reasons why a particular wood should be used. . . . probably the hardest is lignum vitae . . . used for thrust bearings. . . . Balsa wood is so soft it is used to pack furniture as it will not scratch the finest finishes even in direct contact.[1]

The manipulation of wood involves many processes with possibilities of variation in many of them. Means of cutting and shaping wood, finishes and how they may be applied, even the choice of wood to use for a specific

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[1]G. E. Ivy, The Physical Properties of Lumber (Hickory, N. C.: The Southern Publishing Co., 1934), p. 1.

purpose--all these are problems that must be decided by the one who works with the wood. For decisions to be intelligent and the work to progress satisfactorily many concepts are needed.

From the writer's experience, interviews with teachers, and investigation of books written for the woodworking area, the following concepts concerning the structure of wood appear to be of enough general applicability and importance to merit consideration and development in an industrial arts shop:

1. A concept, basic to all others, of the cellular and fibrous nature of wood.

2. A concept of the grain of wood, its cause and methods of sawing to display it.

3. A concept of hardwood and softwood, definition and characteristics.

4. A concept of the hygroscope character of wood and the nature of seasoning.

5. A concept of the cleavability of wood.

6. A concept of luster of wood.

The Cellular and Fibrous Nature of Wood

In the woodshop a knowledge of the structure of wood seems important so that the tools may be applied to it most effectively. As Desch has said, ". . . the best approach to the study of wood is by way of the tree of which it was formerly a part."[1] The tree and the lumber from it are organic and are therefore composed of cells. In processed lumber the cells are dead, but lumber processors seek to condition the cells to give the lumber a degree of stability and workability. In practically any woodworking activity, the industrial arts student is working with cells; hence, the greater the degree of his appreciation of the nature of the cells of the tree, the more effective he will become in his efforts with his project.

The cellular structure of lumber is such that the cells, lignin, and associated chemicals are determining factors in the strength, hardness, and grain of wood, and influence the manner in which wood is shaped, finished, and fastened. Knowledge of the cellular structure of wood would seem an essential for a really intelligent use of the material. Desch helps to understand the cellular nature of wood when he says:

> The cell walls of all plants may be visualized as a series of thin, concentric layers or sleeves . . . The ultimate composition . . . are the molecules of cellulose, a substance composed of carbon, hydrogen, and oxygen. . . . In the cells of wood, cellulose is associated with other substances, the most important of which is lignin. To this latter substance wood owes its stiffness.[2]

The cells of wood are organized to permit the tree to carry

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[1] H. E. Desch, Timber, Its Structure and Properties (London: MacMillan and Co., Limited, 1938), p. 14.

[2] Ibid.

on the functions of life such as conducting liquid plant food from the roots to the leaves, holding the tree erect, storing resins, etc. As a result of these activities, the cells show definite characteristics when the tree is made into lumber. They give lumber its strength and appearance.

The part of the tree used in lumber--the "wood"--is the tissue known as the xylem. In a living tree this tissue consists of several kinds of cells of varying length and diameter which function in conduction. These cells all have relatively thick walls of cellulose which is the characteristic material of wood. The size to which these cells develop before the deposition of cellulose in the walls varies with the available food and moisture supplies. When these are plentiful, as in spring, the cells become relatively large. When they are scarce, as in droughts or late fall and winter, the cells are small. In the climate of Iowa, for instance, the seasonal variation in food and water supplies, with the resulting changing cell size, gives rise to the annual rings in the wood. In addition to the conducting cells, the xylem has bands of thinner-walled, rectangular, pith-like cells that extend radically across the stem. In the tree they function to carry materials slowly across the stem.

In a tree only the outer few inches of the xylem are living and functional. This is usually light in color and known as the sapwood. In a large tree most of the xylem consists of dead cells which make up the heartwood. The heartwood often has a characteristic color--the red of cedar, the brown of walnut. This color seems to result from the use by the plant of the dead xylem cells as a depository for waste products of the metabolism of the living part of the tree.

Cells, though small, are readily seen at low magnifications with inexpensive equipment. Sometimes even common magnifying glasses are suitable. Because most students at the age at which they begin formal instruction in woodworking are very intrigued by the use of magnifiers, it would appear profitable to include simple magnifiers in the shop equipment and to encourage the students to make use of them on the various types of lumber they have occasion to use. Then in helping a student to make decisions as to which type of lumber to use for a particular project, the teacher could call attention to the differences in size of cells, arrangement of cells, and other cellular features that affect the strength, cleavability, color, grain, and finishing properties of the lumber.

There will be occasion in considering all of the concepts of this chapter to refer to the cellular nature of the wood and the associated characteristics because basically this underlies all of the operations performed on woods, the uses made of woods, and the limitations of woods. As will be mentioned, the grain results from the organization of various types of cells. The cleavability of wood depends upon the linear arrangement of the cells and the amount of cementing between them. Similarly, the hardness of the wood depends upon the size of the cells and the relative thickness of the cell walls, as does the type of finish a specific kind of wood will take. In the light of all the ramifications of the cellular nature of wood, this would seem to be an important concept to develop, one on which school time and effort should be spent.

The Grain of Wood

Almost all industrial arts teachers have a more or less accurate perception of what grain in wood is. Often, however, this knowledge is superficial, and it is easily negated commercially by surface treatment. In many cases, this negation also has consumer implications, denying the individual aesthetic pleasure a greater appreciation of fine wood and surface treatment could bring. True insight, on the other hand, enables the mature craftsman to infer from a rough board the final project.

Cells of different characteristics combine into the grain, some types of which have been described:

> By grain is often meant the lines formed by cutting the rings of annual growth. If a stick is cut from a log in such a way that these lines run diagonally from one edge of the stick to the other instead of parallel to the edges, the load that it will carry . . . will be considerably reduced. There is, however, another kind of cross grain, known as spiral grain . . . the wood of conifers may be considered as built up mainly of elongated cells running lengthwise of the trunk . . . Not infrequently, the cells of which a tree is built up

will follow a spiral course around the pith instead of lying vertically.[1]

There are other factors concerning useful cells for practical woodwork. As Desch puts the matter,

> Certain . . . factors also govern the details of the gross features such as a colour sapwood, heartwood, and growth rings, which are readily seen with the naked eye, and enable one to assess the quality of timber.[2]

In addition to revealing the annual rings, grain in some woods can be revealed by cutting the medullary rays, the rows of pith cells extending radically through the wood (xylem) cells of the tree. Often these extend up and down the tree for several inches. Cutting parallel, tangentially, or across these rays gives varying grain to the finished lumber.

Further variation in grain may result where the wood cells curved, as at a branch, or where the cells were deformed or forced to grow in abnormal directions because of damage by injury or disease. Bird's-eye maple is perhaps the best known of these latter. Since different trees grow at different rates, the width of the annual rings vary. Different species also vary as to the amount and distribution of the medullary rays. This variation accounts not only for the varieties of grain found in lumber but also for the

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[1]H. S. Betts, Timber, Its Strength, Seasoning, and Grading (New York: McGraw-Hill Book Co., 1919), p. 52.

[2]Desch, op. cit., p. 33.

consistency of grain in any one species.

Lumber, of course, can be sawed from logs in ways which will show the grain, when finished, to best advantage. Sawing the log completely through from end to end with parallel cuts yields boards of flat grain, often very pronounced as in fir, and edge-grained boards with a very rhythmic grain, enjoyed in a number of applications. The log can also be divided into quarters and each quarter sawed. "pieces shall be considered quartered when 80% of the surface . . . shows the radial grain at an angle of 45 degrees or less with one face."[1] These attractive grains are achieved by cutting across the medullary rays of wood and across other specialized cells.

A knowledge and understanding of the grain in wood and how it is caused should result in an increased ability to select lumber for a specific job and the ability to choose pieces with attractive grain for exposed surfaces where beauty is a feature, or to select pieces cut for greater strength or for less warping because of the "run of the grain."

Users of wood soon come to recognize certain kinds of wood by the pattern of the grain. To help industrial arts students develop this facility and also to recognize the affect of various methods of cutting on the same kind

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[1]Ivy, <u>op. cit.</u>, p. 11.

of wood, teachers can have in the shop, displays, perhaps prepared by students, of wood samples cut in various ways and finished to show the grain. Attention could be called to these in deciding desirable lumber to use for projects.

Hardwood and Softwood

Another factor concerning the cells of wood which is contributory to the development of an understanding of lumber in whether the cell walls and associated lignin are hard or soft from a purely physical point of view. Woody cellulose is the same for all kinds of woody plants, although the materials the cells contain may be quite different. Botanists divide trees into the classification of hardwood if they are deciduous or drop their leaves seasonally. Other trees are classified as softwoods, if they are coniferous such as pine trees. According to Wood Handbook,

> The terms "hardwood" and "softwood" have no direct application to the hardness or softness of wood. In fact, such hardwood trees as cottonwood and aspen have softer wood than the white pines and true firs, and certain softwoods, such as long-leaf pine and Douglas-fir, produce wood that is as hard as that of basswood and yellow poplar.[1]

Industrial arts students might easily become confused if sight were lost of the fact that it is the physical hardness and strength of wood that is important in using lumber.

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[1]United States Department of Agriculture, Wood Handbook: 1955. Agriculture Handbook Number 21 (Washington: Government Printing Office, 1955), p. 5.

"Lumbermen divide wood into two general heads, hardwood and softwood. In a general way we may say hardwoods are used for furniture and softwood for building."[1] Ivy points out that there is bound to be a great deal of interchangeability of hardwoods and softwoods. The industrial arts student may well ask, "When is a wood hard, and when is it soft?" Terms such as these revert back to laboratory tests. As in other fields, special instruments are used to get a consistent index of hardness. Ivy describes them:

> In the case of wood it is . . . the load in pounds necessary to imbed a steel ball .444 inch in diameter to a depth equal to one half its diameter. . . . These tests were made on air-dried stock of approximately 12 per cent of moisture. However, the term "hardness" does not necessarily mean durability.[2]

Knowing the difference between hardwood and softwood is important. If he has mastered this distinction, the student can use good judgment in applying tools and force to working with specific woods, in selecting wood for specific uses, and in substituting one kind of wood for another.

Further, it allows him to understand why certain industrial uses of wood require certain types. Such knowledge might also enable him, as a farm woodlot owner, to make better use of his own resources.

Industrial arts students can be encouraged to devise simplified methods for testing the comparative hardness of

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[1]Ivy, op. cit., p. 21.

[2]Ibid., p. 40.

various wood samples. For example, a weight dropped a standard distance to drive a nail into the wood could be used to develop a comparative standard. While this would not be as accurate as the commercial testing, it would help the students understand the testing process and give a sounder foundation to the development of the concept.

The Hygroscopic Nature of Wood

Once the industrial arts student is able to think of wood as a collection of a great many cells whose function in the living tree is to contain or help transmit liquid, he is almost sure to realize that moisture, particularly moisture in the air, is sure to have an effect upon the cells even after the tree has been processed into lumber. Once he has this knowledge, he is in a position to use wood much more effectively. No kind of lumber seems to be immune to the expansion and contraction of the cells in response to the changing moisture content of the atmosphere. This makes lumber an essentially unstable material and is especially important as lumber is shipped from one climate to another.

In addition to its relation to dimensional stability, the changing moisture content of wood is directly related to its useful life. Once cut, lumber is a rather impermanent material. Alive as in the case of the California redwoods, a tree is our oldest living thing. Shea and Wenger sum it up as follows: ". . . it is known that wood which is kept permanently wet or permanently dry will withstand decay over a long period of time."[1]

Moisture in the air is thus the primary factor in wood stability once it has been cut. Contrary to a popular notion, so far as cutting is concerned, in cold climates it does not make much difference whether the trees are cut in summer or in winter when growth greatly diminishes. It seems to be the residual moisture and the moisture in the air which cause most of the instability. Lowering the moisture content of wood logically seems to minimize the changes caused by the varying moisture content of the atmosphere. However, even with moisture reduced to a low value, rather large changes still occur. Desch indicates this:

> The tendency of wood to shrink or swell with changes in the moisture content of the atmosphere is a factor inseparable from the material. This characteristic behavior of timber is popularly called "working" or "movement." It cannot be eliminated by any particular method of seasoning, storage or treatment, although the deleterious results can be minimized by taking certain precautions.[2]

Poorly dried or green lumber is too unstable to render it useful in commercial construction.

Lumber companies, of course, are aware of these moisture troubles and either dry the lumber by air circulation

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[1] J. G. Shea and P. N. Wenger, Woodworking for Everybody (Scranton, Pa.: International Textbook Co., 1947), p. 13.

[2] Desch, op. cit., p. 81.

through the stacks or by kiln-drying processes. Commercial standards have been established as Ivy indicates: "Lumber which is thoroughly air dried contains about 12% of moisture and if kiln dried about 6%."[1]

In the industry the drying of lumber in kilns is far from cheap, as is indicated in Ivy's description of the processes:

> . . . The process of air seasoning may be carried on over a period of months or years depending upon the thickness and kind of lumber. . . . the lumber is again stacked with spacers between layers for transfer to the dry-kilns. . . . The dry-kiln is a large chamber similar to a tall and elongated garage. . . . Live steam is charged into the kiln, saturating the lumber uniformly with moisture. After a period of time the steam is turned off and the temperature inside is gradually increased to 140 to 160 degrees. . . . for several days, a week or a month until the moisture content drops to a specified requirement.[2]

During the evaporation of the original moisture content from the cells the lumber companies seek to control or minimize the gross changes in both dimension and flatness which occur. These are important to the industrial arts student as well, and are listed by Desch. "Seasoning defects are . . . cupping, twisting, bowing, spring, checks and splits, shakes, case-hardening, and honeycombing."[3] An awareness of how these many potential troubles could affect his project will help the industrial arts student use good

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[1]Ivy, op. cit., p. 21.

[2]Shea and Wenger, op. cit., p. 11.

[3]Desch, op. cit., pp. 132-33.

judgment in his selection of the wood to be used.

The moisture content of lumber may be checked by weighing samples before and after seasoning, or with an electric device which will give an index of the amount of moisture between two small electrodes which are driven into the lumber. The industrial arts teacher probably cannot afford to have such a meter available in his shop. However, without a concept of the effect of moisture and the lumber stability brought about by seasoning, he may find his lumber unsatisfactory when he takes advantage of the occasional opportunity to purchase desired lumber at great savings through other than the usual dealers. Often one hears, "It must be dry, it has been stored in a loft twenty years." Even so, it may not be dry.

The teacher should assist the student to get some idea of how his project is bound to change with moisture. The psychological affect upon the pupil of having a project end up with poor rigidity and cracked surfaces can be quite disappointing. It would be well to bear in mind at all times that, as Shea and Wenger say, "if it were not for both seasoning and the seasoning of the kiln drying process, lumber would warp, twist, shrink, and crack."[1]

In the class the teacher can help the student develop the concept of the effect of moisture by pointing out examples

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[1]Shea and Wenger, op. cit., p. 11.

that come into the shop accidentally, by bringing in other samples, perhaps by conducting weighing experiments on the drying lumber in the shop. One of the obvious changes due to changing moisture content of the air should be recognized by everyone in the changes in the way doors and windows fit and the cracks and squeaks that develop in floors and in furniture during the winter when in some climates the heated indoor air approximates desert dryness.

Cleavability

The tendency of wood to break or split in a certain direction is called cleavability. Record describes it:

> Cleavability is a term used to denote the facility with which wood is split. . . . Splitting involves transverse tension, but only a portion of the fibers are under stress at one time. A wood of little stiffness and strong cohesion across the grain is difficult to split, while one with a great stiffness such as longleaf pine, is easy to split. The form of the grain and the presence of knots greatly affect this quality.[1]

Woods vary in the tightness with which the cells are fastened together. When stresses are set up within the wood for one reason or another, some woods whose cells are less firmly cemented break between the cells along the line of stress. The more readily the cells separate, the greater the cleavability of the wood. Among stresses that may result in splitting are those set up as the wood gains or loses

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[1]Samuel J. Record, <u>The Mechanical Properties of Wood</u> (New York: John Wiley & Sons, Inc., 1914), p. 40.

moisture, as a wedge is driven into the wood, as weight is applied to the wood, or as the wood is bent, pushed or pulled or has other force applied to it. Because of the cleavability the wood may fail to perform its intended function effectively.

The defects and splitting are likely to occur at weak points, much as along the line of the grain, particularly the medullary rays. Breaks can many times be predicted by examining the run of the grain. Knowledge of this is helpful in the processes of splitting and chopping. Experience soon teaches that some logs can be split relatively easily with the grain but must be cut across the grain. Trial also soon teaches that woods without a pronounced grain or with a twisted grain do not split readily.

An understanding of cleavability has importance to the industrial arts student in understanding lumber and in wise selection for his use. It teaches him why a nail should not be driven into a certain piece of lumber in a certain way, or why a small nail should be used. It teaches him why weight bearing timbers should have a straight grain running their full length. Furthermore, it teaches him to be careful about how he tries to bend lumber or how he puts other stresses on it.

Many opportunities arise in an industrial arts shop to point out the effects of cleavability. A teacher should be alert to these from the first experience of the student.

This is a concept that probably should develop early and easily.

Luster

In the many cases where final surface appearance is important for aesthetic appeal, factors other than structural appropriateness also enter in the selection of the wood to be used. One of these is luster, described in these words by Desch:

> Luster depends on the ability of the cell walls to reflect light. Some timbers possess this property to a high degree, e.g., East Indian Satinwood, Lauan, but others are comparatively dull, e.g., Hornbeam. As a rule, quarter sawn surfaces are more lustrous than flat-sawn, and if stripe or ribbon figure is present this figure is considerably enhanced in timbers possessing a natural luster. Although luster is an asset in a cabinet timber, from a practical viewpoint the capacity for taking a good polish is quite as important, and the two do not necessarily go hand in hand.[1]

The purpose of a finish on wood is twofold: (1) to best display the configuration and luster of the wood and (2) to protect the surface in the best practical manner. The teacher should encourage students to examine samples of finished and unfinished woods that do and do not show luster in order to be able to recognize it and the conditions when lustrous wood is desirable.

Summary

The characteristics of wood important to the woodworker seem rather constant. Well-known types of trees

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[1]Desch, <u>op. cit.</u>, p. 49.

continue to furnish the bulk of the lumber year after year. Generally speaking, older knowledges remain useful. "Cleavage" reminds one he should not drive fasteners in a certain direction. The worker knows ahead of time about how lumber of a certain wood "cuts" and what configuration of the grain will finally result. For certain kinds of jobs the most suitable wood for maximum strength, beauty and durability is hardwood. For other uses softwoods, sometimes less expensive and more plentiful, are as satisfactory or even preferable. An understanding of the instability of wood with varying moisture conditions causes one to select seasoned lumber except for the very roughest uses.

CHAPTER VI

CONCEPTS IN THE METALS AREA

Metalwork, a Common Industrial Arts Activity

Next to the use of wood in the one-teacher shops the use of metals as an industrial arts material was the most common discovered activity. This, the metals area, is the second one selected for the determination of concepts that might be developed in an industrial arts shop. The same limitations of and qualifications concerning the selection of concepts apply in this area as were applied in the area of woods.

As with those concerning wood, concepts regarding metals do not form mutually exclusive groups. Concepts listed in one group may also be important in another group, also, some concepts in one group may be necessary for the comprehension of concepts in another group. Probably no concept develops in any area that does not bear some relation to all other concepts in that area and often in other ones as well.

In school visits by far the most common class discussion encountered which related to the crystalline structure of steel had to do with the overheating of hand tools when they were sharpened on the tool grinder. In every case the groups were aware of the fact that if the heat developed from the grinding operation became excessive, the ability of the tool to hold an edge might thus be destroyed. To the end of preventing this the tool was regularly dipped in water to cool it. No attempts to retemper an overheated tool were observed. The most common broken tools encountered were screwdrivers, and these fractured surfaces presented excellent opportunities to observe and discuss the crystalline structure of steel and the proper care and handling of tools. In most cases the instructor pointed out that the tool had been misused by overtaxing its strength. Broken machine parts also aroused considerable curiosity about the crystalline structure of the fractured surfaces. These surfaces were usually a bright gray, denoting they were alloy steel. Broken machine screws showed these characteristics also.

In almost all of the schools, the pupils had an opportunity to weld. They used either oxyacetylene or arc welding equipment. It was a universal practice to have the pupil break his practice weld in a vise by use of a heavy hammer; thus, the pupils proved to be learning how to detect a brittle fracture from a normal one by observing the differences in crystalline structure. In each of these instances the equipment and the materials were kept the same so that the procedure of welding was the variable. In one school, in addition, the welds were being sectioned, polished, and etched with acid to determine the amount of penetration and fusion. This could be detected by observing the difference in the texture of the welding rod and the base metal.

Several schools had aluminum ingots on hand for use in the foundry area. It is common practice to separate the ingots by breaking the thin web of aluminum which holds two ingot sections together. These freshly fractured surfaces with their large crystals clearly pointed up the differences between a fractured aluminum surface and one that had been machined. Coarse, granular crystals of this type required practically no magnification to make a vivid impression upon the pupil.

It is believed that the opportunities for acquainting the students with a basic understanding of the crystalline structure of metals and the relationship of these crystals to the strength, hardness, ductility and other factors related to the commercial use of metal are greatly underdeveloped in industrial arts shops. It is often being subordinated to purely trial and error activities which can scarcely hope to illustrate the large outlays of industry designed for mass production. Hence, it would seem wise to emphasize basic understanding of the crystalline structure of metal far more than is now done.

Concepts Related to the Structure of Metals

In the discussion of concepts relating to wood it was shown that some understanding of the basic structure of wood is needed before an understanding of its treatment can be achieved. So with metals, before an understanding of the uses and handling of metals can develop, an understanding of their basic structure is essential. As almost all of the concepts relating to wood are tied to the basic cellular structure of the wood, so most of the understanding of metals, their behavior and treatment, are dependent upon an understanding of their molecular and crystalline structure.

It is somewhat difficult to select concepts for treatment in this area. On examination, many of what seem to be separate concepts can in reality be considered ramifications of the basic concept of the structure of the metal. However, as was the case in the discussion of wood, these seemingly related concepts are given separate treatment.

The following concepts seem important and universal enough to be included in this section.

1. The nature of a metal.
2. The molecular nature of matter.
3. The crystalline structure of metals.
4. The affect of heat on metals.
5. The affect of the rate of cooling on metals.

In each case the concept iself, some of its ramifications and implications, and its importance to the teacher are considered. Suggestions of activities that might be used to help develop the concept are also included.

The Nature of a Metal

Perhaps the first concept that needs to be clarified, or at least reinforced, in the area of metals in the industrial arts shop is the meaning of the term "metal." The students will have discovered many metals in their previous experience and will have some appreciation of what is meant by the term. However, it seems desirable that in the metals area of the industrial arts shop this concept should be clarified and strengthened.

The definition of metal varies with the purpose of the user of the term. To the chemist interested in all elements, a metal is an element whose oxide forms a base when dissolved in water. Or the metals are the elements on the right hand side of the periodic chart, as usually printed, which have less than four electrons in their outer shells. Hence, they tend to give up electrons when combining with other elements. The metals which find use in industry are materials which have the characteristic properties of a metal and are abundant enough to be easily obtained. Johnson, in disucssing why metals are used says:

> The reason for the increased use of metals is to be be found in their characteristic properties. Most important of these properties is their strength, or ability to support weight without bending or breaking, combined with toughness, or the ability to bend rather than break under a sudden blow. Resistance to atmospheric

> destruction, plasticity, and the ability to be formed into desired shapes add to the remarkable combination of properties possessed by no other class of materials. Some metals also have . . . the power to conduct electric current and the ability to be magnetized.
>
> Metals can be cast into varied and intricate shapes . . . Their plasticity, or ability to deform without rupture, makes them safe to use in all types of structures, and also allows their formation into required shapes through forging and other operations. Metals also possess the important property of being weldable. Of all the engineering materials, only metals are truly weldable and repairable.[1]

Most metals are solids at usual room temperatures. Mercury is, however, a liquid at ordinary temperatures and will be familiar to most students. Other metals that find considerable use in industry and with which the students should probably gain more familiarity are iron and its derivative steel, aluminum, copper, brass, bronze, lead, magnesium, molybdenum, nickel, tin, tungsten, zinc, chromium, cadmium, manganese, and their alloys. While it may be impossible or inadvisable to allow all the students to work with all of these metals, the names and their contribution to the metal industry should probably be familiar. Many of these find no use themselves but are very important in the development of alloys of specific properties.

To shape metals by hammering, cutting, or casting and not to strive for understandings of their nature and industrial properties is to deprive many students of valuable experiences, particularly the abler ones, and to ignore the

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[1] Carl G. Johnson, Metallurgy (Chicago: American Technical Society, 1948), p. 2.

development of understandings, one of the basic aims of industrial arts.

The Molecular Nature of Matter

In wood the basic unit of structure is the cell. However, as we consider metals we find that the basic units are crystals. To understand the nature of the crystals of metal and the changes that occur in them, it is necessary to develop some understanding of the basic structure of all matter--the molecule. The industrial arts shop is probably not the place to attempt an extensive understanding of the structure of matter. This may be better adapted to the science classes. It may be that some of the students have already acquired the concepts of the structure of matter. These are usually included in some phase of the junior high school science program. However, the teacher, in order to do an adequate job with developing an understanding of metals in the industrial arts shop, should have a concept of molecules and their behavior. Through the activities and discussion of the shop, the students could enlarge their understanding of the molecular nature of matter. This understanding is necessary before a student can accurately visualize what is happening within the metal with which he is working as he applies various forces and treatments to it. This understanding is also necessary before the student can modify his treatment of the metals to meet changes and unexpected occurrences during his activity. If he can understand what is happening in the metal as he works with it, then he can modify his procedure when the results are not as he expected.

All Matter Is Made of Molecules of Various Sizes and Constituent Parts

A molecule is the smallest unit to which a material can be divided without changing the material to something else. Molecules are, in turn, built of smaller parts, atoms. Atoms are the smallest units to which a material can be broken down by chemical means and are the units of the elements. Atoms, in turn, are composed of smaller parts about which the atomic physicists are only now in the process of learning. Two of these smaller parts of the atoms are well enough known, however, and of enough importance to some of the work with metals to deserve mention. These are protons, positively-charged particles that lie within the nucleus of the atom and give it much of its weight; and electrons, negatively-charged particles which move in orbits about the nucleus. The number of protons equals the number of electrons.

Electrons Have Definite Orbits in a Series of Shells about the Nucleus

Each shell has a definite number of electrons to make it complete. When extra electrons are present, they orbit in the next outer shell. Thus the light atoms have a small number of protons in the nucleus and an equal number of electrons in a few shells, whereas the heavy atoms have a large number of protons in the nucleus and an equal number of electrons in more shells. The lightest element, hydrogen, has one proton in the nucleus and one electron orbiting in the first shell. Lithium has three protons and two electrons in the first shell with one electron in a second shell. Uranium, the heaviest naturally-occurring element, has ninety-two protons in the nucleus and ninety-two electrons in six shells. However, there are only three electrons in the outer shell. This is of importance, for it appears that the behavior of the element depends upon the number of electrons in the outer shell. One other characteristic of the electrons and their shells should be mentioned. It appears that even though the electrons normally move in the orbit nearest the nucleus until that shell is satisfied, then in the next outer one and so on, a complete set of shells exists in every atom, and the electron may move from one shell to another. If the movement is to an outer orbit, energy is required to make the electron move; if the movement is to a lower orbit, (nearer the nucleus) then energy is released.

Molecules Are Built of Atoms

In some cases the molecule is a single atom. This is true, for example, of iron. In other cases the molecule may consist of two or more atoms of the same element. Oxygen cannot exist in the form of single atoms but always as molecules made up of two atoms. In other cases molecules are made of atoms of more than one element, as water. Most students will know that water is H_2O and that two atoms of hydrogen and one atom of oxygen compose one molecule of water. This represents a relatively simple molecule. Some molecules, though, may contain as many as four thousand atoms. These are some of the proteins found in living things that are so large and complex that their structure really is not known at present. Because cellulose, for instance, is one of these very complex and little known molecules, it seems unnecessary to be concerned about its structure in the wood shop.

The Structure of Metals May Change

Molecules may be broken into their elements and these then made to recombine to form new materials. Or one element may substitute for another in the molecule, thus forming a new compound. These changes are what occur when chemical reactions take place. A number of the things that happen to metals in the work that is done with them in the industrial arts shop are such chemical reactions. Students should be aware of them and of their potentialities and dangers. In addition to the work in the metal area, attention can be called to chemical changes going on in other areas--the finishing of wood, the making of blueprints, the changes brought about by electrical current are some other examples of activities where an understanding of the molecular nature of matter would enable the student to better understand what is happening as he works with the materials.

Molecules Are in Motion

Another feature of the molecular nature of matter has importance in the metals area. All molecules are in motion. All matter is in motion, even in what appears to be the most solid of materials. This is a concept concerning molecules that is difficult for some students to accept because it is so contrary to their perception. It would seem to be impossible for the molecules in a piece of steel to be moving. However, our present interpretation of the structure of matter requires the acceptance of the idea. The rate of motion in any material depends upon the lightness of the molecules and the energy, usually in the form of heat, that is given to the molecules. Once the idea of motion of the molecules is accepted, the rate is not difficult to understand. Analogies from experience are rather obvious --the lighter an object, the farther it can be thrown and the less energy required. Students will usually have met these ideas previously in some of their study of science, particularly in the area of weather.

The concept of the molecular structure of matter, perhaps more than most of the other concepts that are part of the industrial arts shop, is an intellectual concept that it is difficult to develop by percepts. This concept will be slowly developed as the students work with the metals. The teacher can be of the most help as he uses the molecular structure to explain the other properties of metals which can be perceived by the students.

The Crystalline Structure of Metals

In the discussion of the molecular nature of matter it was pointed out that all molecules are in motion. Matter exists in three states, depending upon the amount and freedom of the motion. These are gases, liquids, and solids. In a gas the molecules move freely in all directions with no tendency to adhere to one another. The molecule moves in a straight line until it bounces off another molecule or the sides of a container. Therefore, a gas takes the volume and shape of its container. It can be greatly compressed.

In a liquid the molecules move freely in all directions but tend to be drawn to one another--to adhere to each other. The molecule lacks sufficient energy to escape the influence of the surrounding molecules. Hence, a liquid has a definite volume, a surface tension, and molecular cohesion, but it also assumes the shape of its container.

In a solid the molecules are attached to each other, usually in a reticulum with angular relationships that are characteristic of the particular material. Hence the solid has a definite volume and a definite shape with a definite surface and resistance to having the molecules broken apart. The molecule is not free to move but vibrates in a small area within its immediate environment.

Students may be already familiar with these states of matter and aware that heat may supply the energy to change one to the other. Heat may cause the molecules to increase their rate of movement and thus gain sufficient momentum to escape the effect of the binding forces and thus change from a solid to a liquid then to a gas, or with cooling the reverse may occur. The molecules lose their momentum and change from a gas to a liquid, then to a solid. Materials vary as to their state at what we consider "normal" temperature. So we expect each material to exist in one of the three states and so describe it. Oxygen is a gas, water is a liquid, and iron is a solid.

Water is familiar to most students in three forms: solid--as ice, liquid--as water, and a gas--as steam or vapor. Fundamentally this same substance thus varies in form, depending upon the speed or acceleration of its molecules. Students are well aware that to add heat will change ice to water and then to steam or that to remove heat will reverse the process. They are probably also familiar with dry ice and aware that this is the solid form of the gas carbon dioxide. Many of them will also have read that the normally gaseous oxygen can be made into a liquid which can be pumped into rocket engines.

In applying these ideas to metal work, Henry and Claussen say:

> As a rule we know that solid metals are crystalline. To understand crystals we recall that everything is composed of atoms. An atom consists of a nucleus and a number of electrons. All electrons are alike, electrified particles of negative change weighing 10-27 grams.
>
> The ninety-two different types of atoms differ in size of nucleus and in number of electrons. In the fluid condition whether gas or liquid, two or more atoms frequently combine to form molecules. The atoms or molecules move freely among themselves. In a gas there is a lower limit to the closeness with which the atoms or molecules can be packed by low temperature or high pressure, but there is not an upper limit. In a liquid, on the contrary, the atoms are practically the same distance, center to center, from each other as they are in solids. But the atoms of a fluid may move freely among themselves, and as a result, the fluid is mobile and yields to the slightest pressure.
>
> Since the atoms or molecules of a fluid move freely in all directions they possess very little ordered arrangement. In a crystal, atomic arrangement takes the place of disorder. A well-formed crystal possesses geometrical form; it is bounded by a number of plane surfaces, which are inclined to one another at characteristic angles.[1]

Henry and Claussen continue to point out how a crystal forms:

> We have seen that the atoms of a liquid metal move freely among themselves. When, as we cool the melt, it reaches the freezing point, some groups of atoms fit themselves into the correct position to form a minute crystal called a nucleus. . . . the manner in which the atoms of the nucleus come together is one of the unexplained occurrences in nature. . . . Once the nucleus has formed, the crystal grows . . . The rate at which the metal crystals grow from the melt usually is proportioned to the rate at which heat is withdrawn.[2]

To help students understand this crystal formation and the variation in size of crystals, water is again probably the best example. Solid water is known by students in

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[1] O. H. Henry and G. E. Claussen, Welding Metallurgy (Cleveland, Ohio: The Lincoln Electric Co., 1940), p. 27.

[2] Ibid., pp. 31-32.

two forms--ice and snowflakes. They probably already know that snowflakes are water crystals formed from water vapor and are always six-sided. They may know that for snow to form there must be minute particles or nuclei around which the molecules of water can collect. Then each water molecule that is added takes a definite position with relation to the other molecules so that the crystal shape is maintained. The more molecules that can be added before the snow falls, the larger the flake.

Ice forms from liquid water. Crystals may form in the mass of ice if the freezing goes on slowly. In most cases, however, the cooling is rapid enough that the ice can form without the molecules arranging themselves into crystals, or usually the crystals are very small. Really clear ice has no crystals.

The formation of crystals as a liquid metal cools resembles the formation of snowflakes. If the metal cools slowly more molecules can collect around the nuclei and the crystals become large. If the cooling is more rapid more centers of crystallization seem to develop, fewer molecules collect around each center and the crystals are small. The students may be aware of this same phenomenon in the formation of the various kinds of igneous rocks, ranging from obsidian, with no crystals; to basalt, with very small crystals; to granite, with crystals easily seen; or to pegmatite, with crystals up to two feet in length. This correlates with the rate of cooling of the molten rock material.

Metals, then, are crystalline in structure. This structure varies with the kind of metal and its alloys. The structure also varies, depending upon how the metal was cooled. The crystalline structure of metals largely determines its characteristics of strength, malleability, machining qualities, elasticity, ductility, and many other aspects.

There may be some confusion about the use of the terms atom and molecule in connection with the formation of crystals. The terms are not interchangeable. If the substance is a compound, as water, the molecules are the units of crystal formation. However, in some substances, particularly those that exist as elements, the atoms are the units of the crystal. In metals both forms of crystals may occur. If the metal is pure, the crystals are formed of atoms. If the metal is combined with something else to form an alloy, the molecules of the combination may form the crystal. There are indications from some research in solid state physics that some forms of alloys and compounds form crystals of alternately arranged atoms but form true molecules when the solid melts.

The actual arrangement within the crystal may vary with the temperature of the metal. Iron is an example in which an understanding of this characteristic explains what happens in the heating of the metal. Iron has a cubic crystal. In alpha iron it forms a crystal of nine atoms--one at each corner of the cube and one in the center. In gamma iron there are fourteen atoms--one at each corner of the cube and one in the middle of each side. The gamma iron, because each crystal contains more atoms, is denser than alpha iron. At about 1300 - 1350 degrees F. alpha iron changes to gamma iron as heat is being applied, or vice-versa if the iron is being cooled.

Some understanding of the crystalline structure and the factors that control its development are necessary to understand metals, their treatment and behavior. The teacher can probably best help students to develop these by means of discussion and repetition whenever the opportunity presents itself. Parallels between the happenings within the metal and more familiar materials should prove helpful.

Metals in the pure state do not have very many practical industrial uses. Pure iron (ferrite) crystals are soft, ductile, and weak. Although pure iron is found in some transitory phases of the metallurgical process of producing steel, it soon forms a compound with other materials to form alloys useful in industry. The molecules of such compounds form crystals the size and type of which concern the metalworker.

The Effect of Heat on the Structure of Metals

As has been indicated, according to the molecular theory of the structure of matter the differences in the three states of matter is in the energy of the movement of the molecules. If the molecules are moving rapidly, the substance is a gas; if less quickly, it is a liquid, and in solids the movement is the least. Why this rate of movement should vary in materials at the same temperatures is not exactly known, but such variation seems to be characteristic of the molecules themselves. Apparently it is one of the characteristics of that particular type of matter. One would expect that with the addition of energy to a substance the rate of movement of the molecules could be changed and the state of the material would then change. This is found to be true.

If a metal is heated, the molecules begin to vibrate more rapidly about their points of location; with more heat they escape the points and finally have enough energy that they escape the attraction of one molecule for another and are free to move in any direction. The metal has changed in this sequence from a solid to a liquid and then to a gas. This same sequence will apply to almost any metallic substance. In the industrial arts shop students observe changes in the visible characteristics and behavior of the metal that can be explained by the changes in the molecular activity within the metal.

If heat is continuously applied to metal the accelerated movements of the molecules cause them to swing in wider and wider paths and the metal expands accordingly.

As more and more heat is applied, the atoms or molecules begin to lose more and more of their crystalline affinity and the metal becomes plastic. Slip takes place easily and the metal can be bent and forged conveniently. Still more heat dislodges more and more of this crystalline affinity until the crystalline arrangement is lost and the metal becomes a fluid. Still more heat and the metal becomes a vapor, as is the case in an atomic blast.

In the fluid state the metal pours easily and will assume the shape of any container durable enough to hold it until the temperature of freeze or solidification is reached. This is mainly a relative matter. Mercury, for instance, is metal which is a liquid at normal room temperature (78° F), but it, too, will freeze or solidify as the temperature drops. Conversely it becomes a vapor easily, but at no time did it change its chemical composition. In mercury at ordinary temperatures the molecular cohesion is low enough to allow the molecules to move freely in any direction. Or, conversely, the rate of movement of the molecules is great enough to prevent the holding of one molecule by another in a fixed position.

In the industrial arts metal area the student will see changes occur as he heats a metal which at normal temperatures is a solid. First there will be a slight expansion, an increase in size of the piece. Then the metal will begin to soften and perhaps become deformed by the pull of gravity, As more and more heat is applied, the atoms or molecules begin to lose more and more of their crystalline affinity and the metal becomes plastic. Slip takes place easily and the metal can be bent and forged conveniently. Still more heat dislodges more and more of this crystalline affinity until the crystalline arrangement is lost and the metal becomes a fluid. Still more heat and the metal becomes a vapor, as is the case in an atomic blast.

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In the industrial arts metal area the student will see changes occur as he heats a metal which at normal temperatures is a solid. First there will be a slight expansion, an increase in size of the piece. Then the metal will begin to soften and perhaps become deformed by the pull of gravity, sagging or drooping. If in a container, the solid form will begin to change and the mass to settle into the bottom of the container even though the metal is not as yet liquid. With more heat the metal will become first a thick liquid that can be poured or moved only slowly and then change to an increasingly fluid liquid that runs readily from place to place. There is usually little occasion in industrial arts shop work with metals to heat the material any further. Most activities of the student will involve either the softened or the fluid metal. However, on occasion, as with some types of welding, enough heat may be applied unwisely to cause the metal to either vaporize or to oxidize so rapidly that it is converted to a gas and disappears.

A conception of the effect of heat on metals is valuable in practically any area of a diversified shop where metal is used as a medium, from the machine tool areas of wood (accidentally overheating a circle saw blade) to engine lathe work where heat-resisting (high speed) cutters are used and ground. It should be obvious, if he understands the softening effect that heat has on metal, that if the student lets the saw or cutter become overheated in use the metal of the blade may be softened and cutting effectiveness lost; or if heating does not go to the point of softening the metal that the saw will expand and may warp in the cut, making the cutting process more difficult and dangerous.

The teacher will find opportunity to help the student develop the concept of the effect of heat on the metal by calling attention to the changes that occur in the metal as he first demonstrates the techniques of heating metals, by letting the students work with metals at various heats and by discussing with the students the relation to the molecular nature of the metals. Probably the concept of the molecular nature of the metals can also be reinforced with such discussion at this point. Any time the student has trouble with a saw or cutting edge because of overheating the idea should be recalled. Or any time that precautions against overheating of a cutting edge must be taken, the opportunity is again presented to reinforce the concept of the effect of heat on the metal.

Heat can be applied to metals through the burning of high-energy fuels, although not always as efficiently as with electricity. Carbon, as a rich source of heat energy, ranges in commercial form from coal, fuel oil and gasoline to acetylene gas. So far as metal work is concerned, coal, fuel oil, commercial gas and acetylene are all used to accelerate molecular activity so that metal may be easily formed to useful shapes. Moderate amounts of heat result in plasticity useful in forging. Concentration of heat in a small area faster than the heat can be carried away is a basis of fusion welding. Continued application of heat as in a gas furnace causes metal to reach the melted state in which it can be poured into molds. The small molten pool or puddle associated with welding is therefore called the weld melt. In contrast to the small size of the weld melt in a welding shop are the huge coke gas, or electric furnaces, that can melt tons of metal. This metal can then be poured into molds of some refractory material such as foundry sand, or in molds of other kinds (shell molds).

The Effect of the Rate of Cooling on the Structure of Metals

This concept ties very closely to the one of the effect of heat on metals. Probably one cannot be totally separated from the other. However, it seems advisable to list them as separate concepts in order to better indicate the ramifications and applications of each. This concept also ties closely to the one on the crystalline structure of metals and the idea of the development of crystal size in a material. The obvious effects of various rates of cooling of a metal are the result of the development of the size of crystals that result from such cooling. The student will be able to observe the effects of the rate of cooling in the behavior of the metal involved. The teacher will probably need to help him understand why these effects are produced, and it is at this point that the concept is needed.

Basically the rate of cooling of a heated metal results in the formation of crystals of different size. The faster the metal cools the smaller the crystals and conversely the slower the metal cools the larger the crystals. In general, the smaller the crystals the harder is the metal. When large crystals are present, there is more possibility of movement along the crystal faces within the metal. This movement allows the metal to show some of the characteristics that we associate with softness.

As a molten metal solidifies recrystallization takes place. These crystals can be plainly seen. The most graphic way to enable students to develop this concept is to cool carbon steels at different rates, then to fracture the specimens to show the pupils how the crystals have been effected. Another technique might be to examine broken surfaces of various tools or other steel pieces and then try to estimate the rate of cooling.

An interesting metallurgical variant of the effect of heating and cooling is that copper is generally heated a dull red and then quenched, whereas steel is heated and allowed to cool slowly--both to the same end, a reconstruction of the crystalline structure, in this case, annealing. In fact, the temperature to which a specific steel is heated and the manner in which it should be cooled will vary with the kind of steel. Cast iron will not react in the same manner as steel. These variations and the need for specific information as to how any particular metal will act should become part of the concept that the students develop. The same techniques of allowing the students to try to discover what happens to specific metals under specific conditions will help develop the concept. Further, this type of activity may challenge some of them and stimulate them to an interest that will some day lead to finding answers for the presently inexplicable phenomena in the reactions of metals.

One of the factors that seems to be involved in the variation of reaction is the fact that most metals as used in the shop are not metals in a pure state. They are actually combinations of several materials. These are not necessarily impurities but added materials that give the metal its useful and other particular characteristics. As an example of the importance of these materials in the effect of the rates of cooling and of the importance of the materials other than those of the metal itself, Barnwell describes what happens in steel:

> . . . the main constituents of steel are ferrite, cementite, pearlite, austenite, and martensite. Of these, the ferrite is a conglomeration of iron crystals which are soft, ductile, and weak. Cementite takes the form of crystals of iron carbide which are very hard and brittle. Pearlite is a combination of ferrite and cementite. Austenite is a solution of iron carbide usually obtained by heating the steel above what is known as the critical temperature, while martensite is another solution of iron carbide, but this is obtained by cooling the steel.
>
> . . . if steel is heated and cooled slowly the pearlite and ferrite separate, whereas in rapid cooling, to be associated with the hardening of steel in general, a martensitic condition usually results. Conversely, if a steel is hard by nature by reason of its carbon or alloy content, it can be softened by heating and slow cooling, according to the directions of the steel maker, so that it can be easily machined, the normal properties of such steels being usually restored by heating and

allowing to cool in the air.[1]

> It is the increasing of the proportions of pearlite which increases the hardness and tensile strength but decreases both the ductility and toughness; and increasing the coarseness of the pearlite enhances this effect. Martensite is the hardest constituent which can be produced in steel by heat-treatment alone, so that rapid rates of cooling increase the hardness, but reduces the ductility and toughness.[2]

Anything added to the pure metal may change the effect of the rate of cooling of the metal. For the steel alloys it is often necessary to know the manufacturers specific directions for that particular alloy. Other metals and their alloys behave differently, too.

The teachers visited had numerous metalwork projects underway in which alloyed metal was being cut, bent, forged and welded. Such projects furnish excellent opportunities for introducing concepts related to the behavior of the metal undergoing various shop operations. The depth to which a concept is pursued will naturally depend upon how far the instructor thinks he can successfully penetrate in his shop activities. Capable students will wish to know more about the molecular structure of metals in terms of their shop work. Depending upon the student, his interests and background, particularly if he has a science interest, the industrial arts shop provides many opportunities for the

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[1] George W. Barnwell, The New Encyclopedia of Machine Shop Practice (New York: Wm. H. Wise & Co., Inc., 1941), p. 358.

[2] Ibid., p. 366.

application of scientific principles. Less able students, perhaps in extreme cases, may find their achievement limited to physical activity of a manipulative nature with few concepts of any depth within their grasp.

Industrial arts teachers mentioned that they cannot choose their students in a public school situation and that the "average" student and the low achievers tend to absorb so much of the teacher's time that the superior student is likely to be in danger of being left to shift for himself. In all fairness, the teacher must strive to place himself in a position where he can help the able students achieve some of the more important concepts presented in this chapter. The interested teacher is not likely to find it difficult to develop other concepts adaptable to a wide range of interests and abilities.

Summary

Industrial arts metalwork activities can easily take on a handicraft aspect or a purely manipulative character which to all intents and purposes ignores much of what has been learned about metals over a period of a great many years.

Students perform operations with new equipment upon new metal alloys in their work with projects. They may absorb new manipulative techniques for working with metals by watching the instructor or by observing skilled tradesmen at work. In industrial arts classes there is almost sure to be a number of students potentially able to achieve far greater depth than can be obtained by imitation alone. Such students quite probably will constitute the future leaders in metals and metallurgy. Other students will no doubt wish to know <u>why</u> operations in the metal shop are performed as they are. Students such as these can profit from a knowledge of the crystalline structure of metals, how the character of the crystals affect the properties of metal important to industry, etc. In the process of forging or tempering metal, students can profit by a knowledge of how industry uses heat to obtain a particular crystalline structure for a specific purpose. Concepts in metalwork present a range of difficulty adaptable to a wide range of student ability.

CHAPTER VII

CONCEPTS IN THE DRAWING AREA

Industrial Drawing in Industrial Arts

The area of drawing was selected as one of the areas in which to determine some of the concepts that might be useful to the teacher in the one-teacher industrial arts shop because it is an area that is included in all of the Iowa secondary schools visited. Furthermore, in observing the way that drawing is being taught there seemed to be less concern for the development of concepts than was the case for the other areas considered. The emphasis in drawing seemed to be almost completely on the development of the manipulative skills of making drawings with but little attention paid to developing an understanding of the importance of drawing in industry, of an understanding of the basis of the projections in drawing, or of the development of those drawing skills which might carry over in to adult life. In most schools the drawing was taught through the assignment of pages from a book or manual of plates that were to be copied. This no doubt develops skill in the use of instruments but is not likely to contribute to the development of any real understanding of the area.

As literature in industrial drawing was examined it became more and more clear that it was the mechanics of industrial drawing that receives the greatest amount of attention. This was particularly true with regard to the proper use of drawing instruments and other paraphernalia. It is not difficult to understand why the industrial arts teacher, especially in the one-teacher industrial arts shop situation, should consequently place an emphasis accordingly. In addition, work books and copy manuals are available to help efficiently organize the manipulative activity of industrial arts drawing. It is believed that the writers of the literature cited did not intend that this much emphasis be placed upon copy work and that sample plates and problems to be solved are merely means to help attain two objectives, drawing skill and concept information.

Inasmuch as it is the purpose of this chapter to explore the possibilities of concept formation in industrial arts drawing, attention must be paid to the lesser amount of available information dealing with the "why" of industrial arts drawing rather than to the bulk of the information on the "how" of industrial arts drawing. Consequently, this chapter takes on a somewhat different pattern than the preceding ones. Toward the end of their book something of this idea is conveyed by Pare, Loving and Hill regarding descriptive geometry which is generally considered an advanced aspect of industrial drawing in the following:

> . . . But now that the student has almost completed his course in descriptive geometry, he should be aware of the fact that the really basic principles of the subject are few in number - that the majority of the topics covered are actually applications of these fundamentals to specific problems.[1]

If this is true of descriptive geometry, which by some is considered to be the essence of the theoretical aspects of drawing, it is even more true of the actual drawing itself. Carter and Thompson indicate the same idea in the introduction to their book. Here we find:

> . . . The fundamental principles of engineering drawing are presented according to accepted drafting-room practices after the theory has been presented as a basis upon which to build the practical application.
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> The student should first visualize the object as it would appear in space. He should then draw what he sees. . . .
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> In addition to the training received in making engineering drawings, the student should be taught the reading and interpretation of drawings, the conventions used in executing drawings, drafting-room practices, and should be given a great deal of practice in lettering.
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> The Fundamentals of Drawing are few and not difficult to understand, but proficiency requires constant study, much practice, and a great deal of patience.[2]

In this discussion they outline the concepts that seem to be part of drawing--visualization, reading and interpreting drawings--the conventions used in making drawings, and drafting room practice. The essential aspect of ability to make

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[1]E. G. Pare, R. O. Loving and I. L. Hill, Descriptive Geometry (New York: The Macmillan Book Company, 1952), p. 273.

[2]Isaac Newton Carter and H. Loren Thompson, Engineering Drawing, Theory and Practice (Scranton, Pa.: International Textbook Company, 1943), p. 1.

good drawings seems to be the question of intelligent practice.

In the examination of the literature this was found to be generally true. In some cases there was no attempt to develop much understanding of drawing. The material presented was strictly of the "how-to-do-it" variety, how to sharpen a pencil, how to hold a ruler, how to place guide lines for letters, etc. In a few of the books intended primarily for engineers there was a presentation of some of the why of doing the activity. The greatest amount of discussion of concepts related to the presenting of three-dimensional objects on the two-dimensional paper was found in the books on descriptive geometry. This is not surprising, when considered in overview, for many of the concepts of the projection of drawings are the concepts of geometry, of points, lines and planes. It is doubtful that the industrial arts teacher should attempt to teach many of the concepts of descriptive geometry to the students in the one-teacher industrial arts shop. Of course, on the other hand, it would be helpful if the drawing students have had a previous course in plane geometry.

In addition to the greater emphasis on skill development than on concepts in the industrial arts drawing area there seems to be more discussion of the best way in which to teach drawing. Mattingly and Scrogin indicate some of the ideas as to teaching which they consider to be important in the following:

> Cognizance should be taken of the fact that not all students are endowed with equal powers of perception, imagination, facile coordination, nor memory. The ideal textbook, therefore, should make allowance for individual inequalities, and, by its flexibility, be adaptable to the talented as well as to those who are less gifted. The latter should not be made to feel discouragement by having problem assignments which, at the time, are beyond their comprehension.
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> . . . .
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> The growth generated by thinking out and through a problem is more to be desired than the making of meticulous drawings, though accurate delineation is highly desirable and usually develops naturally along with the more important thought processes.[1]

These authors emphasize the importance of "thinking out and through" a problem and, of course, imply the ability to understand the basis of a problem. They also suggest the importance of adapting the assignments to individual ability within the class. This implies that the teacher has sufficient understanding and background to recognize stages in learning about industrial drawing and to adapt them to the student's need. They also point out one of the aspects that students often find difficult to accept. Many students do not like to make drawings of simple geometric shapes. They want to begin drawing "real" things. For them the following comment is helpful and one that the teacher should realize fully and be prepared to illustrate.

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[1] E. H. Mattingly and Everett Scrogin, Applied Drawing and Design (Wichita, Kansas: The McCormick-Mathers Publishing Co., 1942), p. iii.

> To certain ardent individuals, the drawing of such prosaic forms as cubes and cylinders may lack exhilaration. To them I say, do not despise the simple geometric shapes and solids, because every form, animate or inanimate, that one can draw, is in some way a derivative of these lowly cubes, spheres, pyramids and prisms. A correct drawing of a cube, after searching analysis, is far better than an incorrect drawing of the Empire State Building.[1]

Carter and Thompson indicate one approach that a teacher might use in helping the student realize the full range of the drawings that are needed for the production of a product or a project. This idea may be especially helpful where the teacher asks the students to develop plans for the projects undertaken in the other areas of the shop. The following also emphasizes the language aspect of drawing:

> When composing a theme in any language, there should be included: (a) an introduction, (b) a body, and (c) a conclusion. In the composition of a structure in the graphical language, there should be:
>
> 1. An assembly drawing (introduction)
> 2. Detail drawings (body)
> 3. Bill of materials, specifications, etc., (conclusion).[2]

When the student can present the completed "theme" for his project, he has reached considerable understanding of drawing and its place in industry.

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[1] *Ibid.*, p. vi.

[2] Carter and Thompson, *loc. cit.*

With the lives of so many of our people sure to be strongly influenced by industry, it would seem proper that the industrial arts shop include opportunities for the student in industrial drawing. The kind of drawing to be offered must, among other things, consider the budget of school time for developing industrial drawing skills and the kind of drawing a student is most likely to use in later life. If the student knows why industrial drawing is done in a certain way, learning to draw may be expedited and his progress in drawing encouraged. Industrial arts drawing can easily become so involved with the mechanics and paraphernalia of drawing that utility in later years may be insignificant. The over-dependence upon drawing equipment tends to give the student the feeling he is helpless without such equipment. However, once the basic reasons for making drawings in a certain way are understood and appreciated and it is realized that such drawing of the highest order can be done without an imposing array of equipment, the student may gain a new perspective about the opportunities for graphic expression. Hence the need for concepts of industrial drawing in the industrial arts program.

Because drawing is so definitely a skill subject, the number of concepts involved is less than in the other areas of the industrial arts shop which are considered in concept development. They do not group themselves to any great degree; therefore, each concept is treated separately. In each, something of the importance and application of the concept and what it might mean to the teaching of drawing in the industrial arts shop is indicated. The following concepts are considered:

1. The concept of industrial drawing as a language.
2. The concept of symbols in industrial drawing.
3. The concept of scale in industrial drawing.

The Concept of Industrial Drawing as a Language

On the surface, this basic concept in the industrial arts drawing area seems so obvious and simple that it hardly seems to need mentioning. Yet it is not uncommon to find teachers and students in industrial arts who do not think of drawing as a language, a means of communication. Many students think of it as a skill to be developed and as a technique to be learned but do not realize the ultimate aim of the drawing itself. Yet if industrial drawing is not to communicate ideas, it has little reason for existence. Indeed, the concept as stated seems a simple one about which little needs to be said. However, thought needs to be given to the implications of the communication idea if it is accepted as a basis for the teaching of drawing. If drawing is considered a language, methods of teaching a language probably should be applied to the teaching of drawing.

The Need for an Exact Industrial Language

Berg indicates the need for industrial drawing as a method of communication and the response of industry in the development of a language which is widely understood:

> It is very difficult and in most cases impossible to convey the idea of a mechanical device or to describe in full detail the shape and appearance of a machine or structure in the spoken or written words of a language. Because this is true, the original and natural method of describing objects by drawings has been developed into a universal language known technically as orthographic projection and commonly as mechanical drawing.[1]

French and Vierck develop more completely the understanding of mechanical drawing and what may be accomplished by it as distinct from drawing as an art:

> As distinguished from drawing as a fine art, practiced by artists in pictorial representation, engineering drawing is a descriptive graphical language, whereas art drawing is a means of aesthetic expression. The artist strives to produce, either from the model or landscape before him or through his creative imagination, a picture which will impart to the observer the same mental impression as that produced by the object itself or its visualization in the artist's mind. By employing color, graduation of tone in monochrome light and shade, or line combination in black and white, he is able to suggest his meaning and to depend upon the observer's imagination to visualize the effect of perspective foreshortening and supply the lack of detail.

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[1]Edward Berg, <u>Mechanical Drawing</u> (Milwaukee: The Bruce Publishing Company, 1942), p. 1.

> The engineering draftsman has a more exacting task: Limited usually to outline alone (shading is not often used, except for illustrations), he may not depend upon suggested meanings but must give precise and positive information regarding every detail of the machine or structure existing in his imagination. Thus drawing to him is more than pictorial representation; it is a complete graphical language, by whose aid he may describe minutely every operation necessary and may keep a complete record of the work for duplication and repairs. . . .
>
> In the artist's case, the result can be understood in greater or less degree by anyone. The draftsman's result does not show the object as it would appear to the eye when finished; consequently, his drawing can be read and understood only by one trained in the language.[1]

In this quotation is used the expression found in most writing on industrial drawing, "reading a drawing. Even the use of this expression implies the idea of a language. More will be said of this later.

Art and Science in Industrial Drawing

The line of demarcation between art and science in industrial drawing is far from being a stable one. Art abounds with rules of composition and discussion of design and impression. However, even though the "science" of engineering is becoming dominant, every piece of literature which was examined in the field of industrial drawing made a point of including such more or less subjective factors as arrangement of borderlines, balance of the drawing

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[1]Thomas E. French and Charles J. Vierck, Graphic Science (New York: McGraw-Hill Book Company, 1958), pp. 2-3.

plate, spacing of the letters, weight of lines, optical illusions, pictorial effects and so on. Connotations of all of these are definitely related to the field of art. Lines in a drawing illustrate well the overlap of science and art. The weight of lines incorporates both art for aesthetic aspects and standardized rules of industrial drawing. The precedence of lines, as the precedence of an object line over a hidden line, is more of a rule sanctioned by custom than as an art aspect. There is a standard "alphabet of lines" whose meaning the student will need eventually to learn if he continues far in industrial drawing. The lines and the other standard symbols have a similar relationship to an industrial drawing as do words and grammar to the concepts found in a creative piece of journalism.

Success with words in the use of language as a means of communication varies from clear-cut and definite absolute meanings such as found in the words "none" or "all" to subleties of connotation reaching the plane of dramatic art as far as meanings are concerned. In the field of industrial activity, the delineation of an idea to others has as its goal utmost objectivity and as much universality as possible. In the search for a medium for such communication graphic representation is inevitable. However, the complexity and tone of photographic representation, for instance, excellent in some cases, provės unworkable in others. Simplicity of presentation favors a trend toward stark symbolism and linear contrast. A symbolic and universal language must therefore be learned subject to the least possible amount of dialect and shades of meaning. Dimensions, size and shape must be depicted with an accuracy reducing subjectivity and the effect of personal emotions to a bare minimum. French is very definite about drawing as a language:

> Different courses have been designed for different purposes, and criticism is not intended, but it would seem that a better unity of method might result if there were a better recognition of the conception that drawing is a real language, to be studied and taught in the same way as any other language. With this conception it may be seen that except for the practice in the handling and use of instruments, and for showing certain standards of execution, copying drawings does little more in the study as an art of expression of thought than copying paragraphs from a foreign book would do in beginning the study of a foreign language.[1]

French indicates in this the importance that the concept of drawing as a language may have on the way that the teacher presents the subject. It is interesting to see, however, that in a more recent book French has somewhat modified his stand. He and Vierck say:

> In the past graphic training has emphasized engineering drawing as a language of communication. The textbook "Engineering Drawing," by the authors

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[1] Thomas E. French, A Manual of Engineering Drawing for Students and Draftsmen (New York: McGraw-Hill Book Company, Inc., 1935), p. vii.

> of this volume, promotes the traditional conception and is currently being revised. . . . Nevertheless, it is well understood today that engineering thinking is directed toward the principle that the "art" of engineering is giving way to the "science" of engineering. Consequently, to progress with this new conception, graphic instruction must now not only stress the communication phase but also emphasize the methods and procedures that will accomplish graphic determination and computation.[1]

The change in emphasis is possibly not as radical as it might at first appear. In this respect French and Vierck refer to the use of the drawing aspects of descriptive geometry to aid in the solving of problems of various sorts with which the engineer may be confronted. For the industrial arts student, it is doubtful if this aspect of drawing is so important at his stage of development. Much more geometry is required in using it to solve problems and make computations that can be expected of most students at this level. It seems, then, that the industrial arts teacher should be aware of drawing as a means of communication and help the students to develop this concept. This is the aspect of drawing that will be used by more of the students as a part of their general education. Also in industry drawing finds much more use as a medium of communication than it does as a means of solving problems. Drawing as communication finds use in all phases of production and

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[1] French and Vierck, _op. cit._, p. v.

at many levels, whereas determination and computation are found at the designing engineer's level.

The Concept of Symbols in Industrial Drawing

A language is composed of letters and words, sentences and paragraphs. If industrial drawing is considered to be a language, it, too, must have its letters and words, sentences and paragraphs. The variation of lines has been mentioned as one part of the alphabet. A major part is the symbols that have been developed and standardized for use in drawings. This makes the concept of symbols and their importance one of the basic concepts of drawing. As Olson describes it:

> The language of drawing has an alphabet. . . . Many symbols are used for convenience in drawing and ease of reading. Those suggested here are recommended by the American Standards Association.[1]

The use of symbols, which is the essence of industrial drawing, requires that these symbols have a vivid and personal meaning to each individual as a separate entity and also that these symbols have the character of universality in that other individuals attach (as nearly as possible) the same meaning to them, even though the meaning may have been acquired under psychologically very different circumstances.

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[1]Delmar Olson, et al., Industrial Art in the General Shop (New York: Prentice-Hall, Inc., 1955), p. 19.

As previously indicated, the number of concepts that have been identified for the drawing area is considerably less than for the other areas of industrial arts considered. This seems to be because so much of drawing is involved in the development of skill in presentation and in the use of the "alphabet" of the area. Once the basic concept of the use of symbols to represent parts in a drawing has been accepted, the rest of the learning primarily involves learning the symbols and learning where to place them on the drawing. This is mainly skill, not concept. The use of many symbols will, undoubtedly, help develop the concept of symbols and their use. Naturally the experienced draftsman has a far greater appreciation of the importance of such symbols than does the beginner in the field, but everyone encounters all kinds of symbols every day.

In introducing the use of symbols, Feirer says:

> . . . Most things are too difficult or take too much time to draw exactly as they are. Therefore you will draw symbols instead. A symbol is a very simple drawing of the object. . . . In each area of drawing there is a group of different symbols.[1]

This is the basis of the development of symbols. If the student realizes that the symbols that he is expected to

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[1]John L. Feirer, Drawing and Planning for Industrial Arts (Peoria, Ill.: Chas. A. Bennett Co., Inc., 1956), p. 14.

use are conventionalized or stylized drawings of the part that he is representing, the use of symbols will seem obvious and necessary. Also it will become apparent that there is a need for standardized symbols if the drawing is to be understood by other people. Most of the literature examined which deals with drawing devotes considerable space to the use of symbols. Reference lists are available which include the standard symbols for the various objects, materials, and even colors that may need to be included in a drawing. There are symbols for plumbing and piping, for electricity and radio, for screw threads, for heating and ventilating, for construction materials, for doors and windows and for all other needs of either architectural or engineering drawing or mapping.

It is not necessary that the student memorize these symbols, except those that he may use often. In this circumstance he will learn them by use, not by rote. However, a teacher should be sure to have available in the classroom references in which the standard symbols are available as the student has need for them.

Not only are arrow-heads, dimension lines and symbols standardized and universal but their placement as part of a drawing is also standardized. Furthermore, many teachers think our lineal system should be further standardized by adopting the metric system. If perchance all this could be internationally established, it is then quite conceivable that any engineer or workman could interpret practically all the data on an engineering drawing even though he did not speak the native language of the country in which the drawing was made. When students realize that this is true, they will have an appreciation of the value of standardized symbols in industrial drawing.

The Concept of Scale for Industrial Drawings

The concept of drawing as an exact and universal language has in its background the universality of our numbering system and our mathematical principles. Shades of meaning and personalized interpretation common in a spoken language have little place here. Very seldom are words such as "approximately" or "about" found on a machine drawing, although in architectural drawings a word such as "random" may frequently appear. But even this has a rather definite meaning to the architect and builder. Dimensions are as accurate as the measuring instruments, the materials, and the application demand. The need to use stated dimensions and not obtaining data by measuring directly on the drawing brings about more appreciation of the concept of scale. Even full size or full-scale drawings are seldom accurate enough and placed on paper with enough stability to permit obtaining direct measurements by applying measuring instruments to the paper, particularly in an area like a machine shop where close tolerances may be required.

Many objects for which drawings must be made are too large to fit on the paper generally available if drawn to full size. On the other hand, there are objects for which drawings must be made that are so small that the workman would do a better job of reading the drawing if the object were drawn larger than full size. In both cases the parts and details must be in the same proportion in the drawing as they are in the original object. The recognition of this is essential to the satisfactory production of the object from the drawing. In each case the draftsman or the student in the industrial arts shop must decide before he begins to make the drawing what proportion or scale will enable him to fit the object upon the paper and maintain the best relative proportions. Pare, Loving and Hill indicate the great importance of the selection of the scale and careful adherence to it:

> The accuracy of a graphic solution may be affected by many factors, . . . In the interest of economy of time the draftsman should realize that his graphical results can be no more significant than the original data. . . . the draftsman can select a scale for his work that will help produce the desired accuracy, for it is the scale of the drawing that is perhaps the one factor that most drastically affects the accuracy. For instance, an error of 1/50 of an inch in 8" produces an error of only ¼ of 1% while a similar in 1" produces an error of 2%. Thus it may be stated that the scale should be as large as can be conveniently handled with the available drafting equipment.[1]

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[1]Pare, Loving and Hill, <u>op. cit.</u>, p. 287.

The concepts of scale development and proportion are part of the concepts of mathematics. It is to be hoped that the student coming into the industrial arts shop will have some of these concepts. Otherwise, the teacher may need to take some time to help the student understand the principles upon which the scale is based. There are in general use for drawing three scales: (1) the civil engineer's scale, based on the metric system, the inch divided into multiples of ten; (2) the mechanical engineer's scale, based on the relation of fractions of an inch to an inch; and (3) the architect's scale, based on an inch or a part of an inch to a foot. Measuring instruments with each scale on them are usually available for use by the student. One of the skills that the student should develop is the ability to use the scaling instruments accurately and quickly. Scaling instruments are not generally used to draw lines but only to measure them to avoid damaging the accuracy of the instrument. Students should become aware of this danger and learn to care for tools properly.

French and Vierck indicate some of the problems that the student must meet in the use of scale in drawing:

> In stating the scale used on a drawing, the information should be given in accordance with the scale used to make the drawing. Thus, if a standard mechanical engineer's scale is employed, the statement may read that the scale is (1) full size, (2) half size, (3) quarter size, or (4) eighth size. These scales may also be given as (1) 1" = 1", (2) ½" = 1" . . . If a standard architect's scale has been used, the

> statement will be given in terms of inches to the foot. Examples are (1) 3" = 1'-0", (2) 1½" = 1'-0", . . . It should be remembered that, in stating the scale, the first figure always refers to the drawing and the second to the object.
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> . . . .
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> The two terms scale and size have different meanings: The scale ¼" = 1'-0" is the usual one for ordinary house plans and is often called by architects the "quarter scale." This term should not be confused with the term "quarter size," as the former means ¼ in. to 1 ft. and the latter ¼ in. to 1 in.
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> . . . .
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> The important thing in drawing to scale is to think and speak of each dimension in its full size and not in the reduced (or enlarged) size it happens to be on the paper. This practice prevents confusion between <u>actual</u> and <u>represented</u> size.[1]

In both making and reading drawings the understanding of the general principles involved in the use of a scale for the drawing are needed and also an understanding of the method of recording the scale data on the drawing. Both of these seem feasible for development in the industrial arts shop.

Summary

In this study industrial drawing is considered as separate from industrial designing which is a vast field in itself and one which utilizes industrial drawing as one of its processes.

According to such a view, industrial drawing becomes a language and a technique bearing much the same relationship to the man in industry that grammar bears to the creative writer.

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[1]French and Vierck, <u>op. cit.</u>, pp. 30-31.

According to the literature reviewed, the principles of industrial drawing are relatively few whereas the rules and techniques are many.

Inasmuch as industrial drawing is constantly being referred to as the language of industry and provides effective media for communication in the industrial arts shop, both the techniques and the concepts should probably receive attention in industrial arts.

CHAPTER VIII

CONCEPTS IN THE ELECTRICAL AREA

The Importance of Electricity in Secondary School Industrial Arts

The area of electricity in the industrial arts shop has been selected for inclusion because it offers an opportunity to show how a different type of area can become part of the concept development of the school shop. Of the areas included, electricity is actually taught much less often presently in the Iowa schools than any of the other areas. Furthermore, electricity is a very different area. The medium (electrons) cannot be handled or shaped, cut or fastened. Its very existence, except as its effects are observed, is based on theory, on concept. A student cannot enter the shop very often and begin a project he understands without some previous development of a concept of what electricity is thought to be and how it is handled and controlled. In addition, safety in the management of electricity requires that a student become familiar with some of the basic concepts concerning electricity before he is allowed to work with it. The use of a safe low voltage, exceedingly good practice with young students and beginners, soon is outgrown.

The Electricity Area Differs from Other Areas of Instruction

Electricity instruction appears to differ from other areas of industrial arts whose media is more tangible in that the nature of the electrical charge is purely a theoretical consideration because this force is out of the range of human senses. Knowledge about electricity and its activities is gained chiefly by observing its effect and by using responsive instruments for indication. The bulk of the literature related to electronics which was examined falls into two broad categories; first, "how-to-do-it" instructions for project construction, electrical installation, maintenance, and modernization; and second, discussion of electrical concepts and theory. The vanguard of concept formation lies in pure science, but knowledge gained reaches down to a greater or lesser degree to all employees in the electrical industry. Thus the electricity area differs from the others considered in that the abundant literature of the electrical area contains many volumes of electrical theory to assist in concept formation. In this discussion it seems inadvisable to duplicate electricity textbooks which already very effectively point out that the very essence of electricity is conceptualization.

It becomes the industrial arts teacher's task, then, to select from the many excellent volumes available, the one which suits his situation the best. The problem is not one of searching out the concepts from the vast electrical literature abounding with concepts but of selecting from this literature concepts appropriate to his school situation and within the ability of his students. He needs to select concepts which are basic but which can be taught to his students without destroying the essentially manipulative character of the industrial arts shop and without discouraging the members of the class who may find electrical theory difficult. In surveying literature in the electrical field the only paucity of theory was found in the lower echelons of electrical occupations. Here manipulative skill is the predominant characteristic and technical knowledge is related to well-established, rather rigidly-prescribed ways of carrying out the manipulative activities. Concepts of electricity and its applications are essential to, (1) understand why these requirements are made, (2) participate in any other phase of the industry, (3) have an appreciation of the part that electricity plays in modern life, or (4) be a good consumer.

Since the problem of the teacher is the selection of concepts obtained in available literature, those concepts selected for inclusion in this discussion are suggestive only of the ones that would seem to be feasible for inclusion in an electrical area of a one-teacher industrial arts shop. After the student has been first introduced to the basic thinking of what electricity is, its properties and how it may be controlled, he may profit from manipulative activities and operation of equipment.

Much of the understanding which is gained concerning the electrical energy expended in industrial machines will hinge upon the behavior of the electron as its influence is felt in the components of these machines as they perform their intended functions. The same may be said of the multitude of other electrical devices which one is likely to take for granted as he makes use of them. It is when the proper functioning is interrupted or when new units are purchased or installed that one becomes aware of the complexity and utility of the device and of the skill needed to cope with it. Very often there are no mechanically moving parts as are found in mechanical devices, but it is quite obvious that some activity is normally going on.

Electricity and Electronics

Some preliminary statements seem in order because in the field there is some disagreement about the proper name for the electricity area. In some quarters the entire area is being more and more referred to as electronics because the activities of the electron form the fundamental frame of reference. Two broad designations presently cover the field. Activities involving the vacuum tube are considered as part of the area of electronics, whereas other activities involving electricity but not the vacuum tube are considered the electricity area. The overlap of the two areas is tremendous, particularly in view of the great advances in semiconductors. With full awareness of the foregoing, however, the term industrial arts electricity area will presently be considered as encompassing the activities of the electrons in all industrial circuitry. As in the other areas considered, the industrial orientation of the student is recognized as one of the primary influences upon the industrial arts activities. In connection with the name to be used the attitude of the Radio-Electronics-Television Manufacturers Association (RETMA) which is an organization representing these industries and maintaining a skilled staff for aiding in the training of technicians is valuable. This group represents organized, careful thinking on the part of many individuals in the electrical field, including an advisory committee of men in industry. They preserve the two classifications in two manuals for instruction of trainees in the electrical industry, i.e. Basic Electricity and Basic Electronics.[1]

Furthermore, the industrial arts teachers contacted were of the opinion that the electricity area included some work with vacuum tubes. Among industrial arts shop manuals

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[1] Paul B. Zbar and Sid Schildkraut, Basic Electricity and Basic Electronics (McGraw-Hill Book Company, Inc., 1956).

there are such titles as General Electricity by E. W. Jones[1] and a similar volume by Dragoo and Porter[2] which lend support to the idea that the industrial arts electrical area can include work with vacuum tubes without necessarily changing the title of the area. The standardizing of a title for industrial arts electrical work will no doubt evolve as the field becomes more mature.

As indicated, electricity is less often included in industrial arts programs than are the other areas discussed. Of course, teachers should probably give some consideration in the selection of their areas to relative industrial importance. In this event, the electrical industry has widespread employment possibilities for many different kinds of individuals, particularly from a technological viewpoint. On the other hand, industrial arts teachers, because of their general education approach, should probably not limit their teaching to any particular group to the exclusion of all the others.

Electricity Is Big Business

From at least one viewpoint the electrical industry has a pyramid type of personnel structure. In terms of

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[1]E. W. Jones, General Electricity (Bloomington, Ill.: McKnight & McKnight Publishing Company, 1954).

[2]A. W. Dragoo and C. B. Porter, General Shop Electricity (Bloomington, Ill.: McKnight & McKnight Publishing Company, 1952).

formal education required, the top echelon is undoubtedly made up of the research scientist, design engineer, and the engineering staffs that assist them. Important in the implementing of the work of the top echelon is a group known as technicians. They are not necessarily college trained but often have attended technical schools or participated in trade and industrial training programs. Their mathematics training has been of the "applied" or shop variety. They are particularly skilled in the use of testing equipment and have skills with tools and machines so that they can construct the prototypes of scientific and industrial units and other apparatus to be mass produced later.

In view of the tremendous social impact of the applications of electrical power, the vital importance of the maintenance electrician should be duly considered. His primary function is to see that electrical power dependably performs its functions in existing equipment and is connected to new equipment as this equipment comes into general use. He must come to know effective testing techniques and apply practical concepts of electricity to practical problems. He must be resourceful and gain increasing skill through practical experience. In addition to being a well-adjusted, contributing citizen as should everyone be in the electrical field, the maintenance electrician must gain training, usually beginning with shop work in industrial arts, followed by trade and industrial training, or by an apprentice-training program.

New residential housing units, industrial plants, and commercial buildings are being constructed at an unprecedented rate. Each of these requires extensive electrical wiring under at least minimum standards prescribed by law in most communities. The many thousands of jobs thus provided are characterized by manipulative skill primarily and by a thorough knowledge of procedure prescribed by rigid electrical codes. The electrical installer's day is a busy one, mounting fixtures, handling assembly line manufactured electrical components, bending conduit, making connections, and splices being some of his major tasks. Except in troubleshooting, no great amount of time is consumed in abstract thought or in academic contemplation. absolute trustworthiness and the ability to put in a good day's work are more characteristic of this kind of an electrical occupation.

Importance of Electricity in Industrial Arts Instruction

If industrial orientation is accepted as one of the primary aims of industrial arts, the employment possibilities for many different kinds of people in this vast, evergrowing industry can scarcely be ignored. Neither can the industrial arts teacher rationally place all his electrical instruction on such a theoretical academic plane that only a small fraction of his class can assimilate it, i.e. the future scientists, engineers, and technicians. Although this segment of the student body is immensely important and industrial arts can stimulate their discovery, some attention must also be given to the far greater number who will bear the brunt of the physical work of the electrical industry.

It seems to be more and more recognized, also, that industrial scientists and engineers who do not understand how goods and services are actually produced on a commercial basis are partially illiterate and handicapped. It would seem wise, therefore, for an industrial arts teacher to begin his electrical instruction with essentially manipulative activities which most of the students can accomplish; with enrichment to challenge those of superior abilities. As the instruction moves toward the acquisition of the all-important "background" a selective process is almost sure to set in as the teacher and student discover the phase of the industry most promising of individual success. Students who seem to be high achievers in the realm of theory should obviously be encouraged to take more advanced shop courses and to enroll for all the mathematics and appropriate science courses possible. If the electrical shop work cannot be set up on a unit basis, then, most certainly, facilities must be provided in the general or diversified shop so that those who survive the selective process can at least get some practical experience with vacuum tubes and transistor circuitry. Duplication of physics courses seems neither appropriate nor sufficient, although industrial arts and the sciences are inseparable, one expressing the industrial implications of the other.

Industrial arts electricity may have implications for some industrial arts teachers if their industrial arts programs are not to fall hopelessly out of date. Lack of instructor background or the suggestion that electricity is a dangerous shop subject seem less and less acceptable as reasons for ignoring a field as vast as this.

As previously suggested, the more electrical theory one possesses in addition to practical ability the more he can generally advance in the electrical industry. As with the development of the concepts in the other areas of industrial arts, practical limitations of time and facilities enter the school shop picture. The Radio-Electronics-Television Manufacturers' Association suggest that in their programs theory should be presented and that theory is important to advancement:

> This is one of a series of RETMA basic laboratory manuals. It is developed primarily for the training of radio and television technicians. However, the practical skills and the electronic concepts which mastery of this manual will assure provide a firm basis for specialized training in any field of electronics. The laboratory manuals correlate laboratory experiments and work projects with classroom instruction. Moreover, they deal with the current products,

practices, and techniques of the industry.[1]

This bears some similarity to the learning of a new language by stressing the conversational aspects as against stressing an accumulation of a vast background of grammar and vocabulary before stressing conversation. They also suggest that their approach to teaching not only the skills but also the principles, or concepts, is through a program of activity and manipulation of equipment and that some classroom lecture or discussion is helpful:

> The manuals provide a laboratory program closely correlated with recommended classroom instruction. By using up-to-date equipment and by following a logical sequence of jobs in which he learns basic technical skills, the student is taught electrical, electronic, and radio principles which are integrated with work on commercial products of the industry.
>
> The objectives and required materials for each job are clearly set forth in simple, easy-to-understand language. The introductory information includes a comprehensive discussion of the theory and practice relating to that specific job. Basic principles, techniques in the use of specific instruments, and circuit parameters are discussed; and the effects of variation of these parameters in circuit operation and performance are emphasized. At the end of each job, questions are posed to test the student's comprehension of the completed work.[2]

It would seem that possibly industrial arts teachers who are concerned with developing concepts of the electrical area through the industrial aspects rather than the research aspects used by the science classes might profit by suggestions

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[1] Paul B. Zbar and Sid Schildkraut, Basic Electricity (New York: McGraw-Hill Book Company, Inc., 1956), Foreword.

[2] Ibid., Preface.

from these manuals.

Industrial arts electricity, as it is often encountered in the schools today, involves the making of such projects as toy electric motors, toy telegraph keys, toy buzzers, etc. The bulk of the activity involved in making these projects is metalwork and woodwork with but insignificant proportion of time involved in the project concerned with anything primarily electrical in theory. In a multiple-activity shop, the woodwork and metal work can be considered as natural to these areas and then such electrical projects seem perfectly logical. This is, however, not a reflection of the condition in the electrical industry as the electrician does not try to compete by hand work with the factory assembly line production of electrical components. The design engineer and his technical staff must, of course, build by hand the prototype of any new electrical component to be later mass produced. This is a minor group as far as numbers employed in the electrical industry are concerned.

Industrial Arts Electricity in Iowa Schools

At this point and in the light of the overview just presented, it seems appropriate to describe the industrial arts situation in Iowa with regards to electrical areas, before proceeding with the discussion of feasible concepts.

With one exception, the Iowa high school teachers said they had not had much opportunity to take courses in industrial arts electricity. As a matter of fact, only a few had formed a clear opinion as to how industrial arts electricity might differ from the sections on electricity in general science courses or in physics. Almost all of these teachers had an awareness of the unparalleled growth of electrical work as an industry and were fully aware that very large numbers of people gained their living in phases of this new industry in which laboratory training (in the collegiate or scientific sense) is not always absolutely necessary. They said they knew also that the production-line manufacturing of electrical equipment absorbed only a small part of the total manpower in the electrical field. Installation, maintenance, and modernization of electrical units was going on about them in homes and in industry at an unprecedented pace. They had only to step outdoors to see the hundreds of television antennas installed on all sides.

There seemed a definite uneasiness among the teachers thus aware of the import of electricity to our society and who were not presently doing much to make their industrial arts shops responsive to this situation. Some of the teachers who had taken one or more of the few available industrial arts electricity courses for teachers in Iowa had commendable instruction underway. Others who had taken courses while in military service to help carry on what is often called the "technicians' war" were doing very well also. Surprising though it may seem in reference to some of these latter teachers who had good electrical backgrounds of considerable depth, their teaching often "went over the heads" of the rank and file of the pupils and hence served no useful purpose for them.

It seemed quite plain as discussions followed one another that the problem of industrial arts electrical activities must be approached at a far earlier stage of development than woodwork activities, for instance, would have to be. For comparative example, most of the teachers seemed aware of the industrial implications of woodwork and that the principal activity in their industrial arts shops--cabinet or furniture-making with wood--was probably not of the most significance in terms of the manpower distribution in industry. Tradition, teacher background, and community pressure plus ease of adapting such woodwork activity to the school situation were reasons given for this emphasis of woodwork. Some teachers, however, were aware that carpentry, particularly that utilizing power machinery and equipment, is actually very significant industrially. Implementing this carpentry phase in the school situation was a source of much more trouble than was furniture construction. On the whole, however, making associations of industrial arts to present day industry was making some progress in these respects.

Industrial Arts Electricity and the School Curriculum

To be able to meet other areas on an equal footing, industrial arts electricity would need some clarification before concepts would be valued and utilized by the teachers. As an industry, electricity is more recent in its development than the industries to which industrial arts woodwork and metalwork are related. This is probably a major reason why teachers have less familiarity with the area and hence include it less often. Furthermore, administrators are often slow to accept movement away from the traditional patterns of the curriculum. This makes especially necessary an organized development of concepts and related activities in the area of electricity so that it will be widely included as an industrial arts area.

Discussions with secondary school teachers and colleagues showed that some serious consideration of how to make industrial arts electricity more realistic is going on. Electricity teachers find it necessary to keep a good liaison with workers in the electrical industry to help keep up with the rapid advances in industrial electricity.

In keeping with the industrial implications of industrial arts, some aspects of work in the electrical industry will be mentioned because of their implications for implementing the industrial objective of industrial arts. These are some of the important general aspects of the electrical industry of which an industrial arts teacher probably should be aware. These were mentioned by the teachers:

1. Large numbers of persons in the electrical industry work with equipment and components which are already manufactured and perform jobs involved primarily with installation, maintenance and modernization.

2. A large portion of experimental electrical work is done by processes which include the assemblying of factory-manufactured components and testing with factory-made test equipment.

3. Much of the know-how of practical electricians is obtained as the needs of the job arise.

4. Valuable trade practices and desirable techniques do not always appear in print. This makes an instructor with real trade experience or possessing a close contact with industry particularly valuable.

5. A number of electrical jobs require much ability to accept responsibility. Great expenditures of money, for instance, are involved in large powerplants, sub-stations, and distribution systems. Ability to be faithfully vigilant and alert to foresee trouble is valuable and distinct from passive presence on a job.

6. For reasons of safety and efficiency many of an electrician's activities for pay are circumscribed by codes and regulations, such as the National Electric Code.

Electricians must develop a sense of responsibility, in order to distinguish between situations where activity is thus prescribed and those in which their own creativeness may be permissible.

7. Because electrical phenomena are often almost instantaneous in their effects, electricians must learn to be deliberate and cautious in much of their activity. They must learn to resist fatigue, distraction, and what could be lethal vacant-mindedness.

Specifically, for industrial arts teachers themselves, these suggestions appear to be useful:

1. Present related information and theory primarily when the student feels a need for it in conjunction with his manipulative activity and do not attempt to present a thoroughly comprehensive theory background at the expense of student manipulative activity time.

2. Provide enough similar projects to permit some repetition of the basic principles involved.

3. The building of small electrical items, such as toy motors, etc., from wood and other materials which are not prefabricated, may involve a disproportionate amount of time not representative of activity common in the electrical industry. If related to the other areas of a diversified shop, such as wood and metal, they appear to be justified.

4. Learning about electricity requires a certain amount of consistent concentration for extended periods.

Each item of information, though not in itself difficult, may be likened to links in a chain. Without the previous links the new link may seem unrelated.

5. Learning about electricity may baffle those who may try to grasp it in its entirety and all at once.

6. A popular way of beginning electrical circuitry is to have students connect bells, buzzers, and push buttons in various combinations. A danger here lies in the fact that this may become a coded, regimented activity particularly discouraging to able students.

7. Electricity, although not nearly as widely included in industrial arts programs as is work with wood and metals, has a definite appeal to students and offers many possibilities for developing concepts that are closely tied to industry. The possibilities of future development in the area appear greater than for any of the others considered.

Concepts Related to the Behavior of the Electron as a Source of Energy

As is the case of wood and metal, before an understanding of how the material finds use in industry, why it is handled as it is, and the nature of its strengths and its limitations, it is necessary to understand something about the material, its characteristics and behavior. So in the work with electricity it is also necessary to understand the medium somewhat before one can develop concepts of the industrial aspects of the use of the medium. The consideration of concepts relating to the behavior of the electron as a source of energy as those that deal with the medium and its characteristics.

Electricity Is a Form of Energy

It is necessary first to recognize that the medium with which the student works in electricity differs from the media of the other areas considered because electricity is a form of energy, whereas the other media are generally physical materials. Although in the past, there has been considerable discussion among scientists as to what electricity is, Cheronis, Parsons and Ronneberg indicate some of the evidence that is readily recognized today in ascertaining that electricity is a form of energy:

> That the electric current which flows ordinarily on copper or aluminum wires is a form of energy is indicated by two facts. First, it is readily converted into other forms of energy, heat by the incandescent lamp, mechanical energy by the motor, and chemical energy by the electrolytic cell. Second, the electric current is always generated by the expenditure of one of these forms of energy and a "static" charge is also developed by the use of mechanical energy.[1]

Need for Different Approaches in Teaching Electricity in Industrial Arts

Some students may enter the industrial arts shop with many of the concepts of the behavior of the electron and its relationship to the development of electrical energy.

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[1] Nicholas D. Cheronis, James B. Parsons, and Conrad E. Ronneberg, The Study of the Physical World (New York: Houghton Mifflin Company, 1950), p. 648.

In most general science courses at the junior high school level and in many of the science activities of the elementary school units on electricity are often included. In these, concepts of the nature of electricity and of the related behavior phenomena are developed more or less completely for that age group. In addition, if any of the students have had physics, they will have studied a good deal about the electron and electricity.

The presentation of the basic concepts in the industrial arts shop should not be a duplication of the science classes. In the science classes the approach is usually that of the historical development of the understanding of the area, or of the somewhat mathematical experimental approach. The primary attempt is to develop a broad background of concepts and not necessarily to enable the student to solve the practical problems of the specific industrial mechanisms that use electricity. The industrial arts activity should also be aimed at developing some of the concepts basic to the understanding of electricity and its behaviors but in addition should enable the student to work with the various industrial mechanisms that use electricity. Some of the same concepts may be developed in each class as far as the basic elements are concerned, but the method by which they are taught and the related learnings will differ.

Electron Movement as a Source of Electric Current

Although the exact nature of the electric charge has as yet not been defined by scientists, the effects of it can generally be observed, understood, and controlled. Much investigation has been concerned with electrical phenomena over a considerable period of time. As indicated, this historical approach to the understanding of electricity does not seem to be the most effective one for the industrial arts shop. However, if the teacher or interested student wishes to follow the development of the concept of the electric charge, it is well presented by Roller and Roller:

> Today the accepted view is that in every substance there are two different kinds of particles that play a primary role in all common electrical phenomena. One of these is the proton, which has a positive charge and the same mass as a hydrogen atom. The other is the electron, which has a negative charge and a mass approximately 1/1800 that of the proton. These protons and electrons are present in equal numbers in any unelectrical substance.
>
> In a solid substance, the protons are in fixed positions, but the electrons are free to move. . . . In solid metals, . . . many of the electrons in the metal are free to move about. Thus, if one connects two oppositely charged metal objects by a wire, electrons stream along the wire from the negatively to the positively charged object, constituting an electric current. In brief, in solid substances there are two "fluids" and yet only one "fluid." There are two "fluids" in the sense that collections of both positive and negative particles are present. There is one "fluid" in that only the mobile electrons are involved in any transfer or "flow" of electricity. Incidentally, it is seen that this single, mobile "fluid" consists of negative electricity, rather than positive, as Franklin had assumed.
>
> In a liquid or a gas, electrical conduction is due chiefly to ions. These are charged atoms or molecules. An atom or a molecule is uncharged when it contains

> equal numbers of protons and electrons. It becomes a positively charged ion if it loses one or more of its normal quota of electrons, and a negatively charged ion if it acquires one or more extra electrons. In a conducting liquid or gas, both positive and negative ions are present, and these move simultaneously and in opposite directions. Here, then not only are there two kinds of "fluid," but both kinds are mobile, in conformity with the old two-fluid picture of conduction.[1]

The reference to "fluid" in the statement refers to the explanation of electricity that existed almost to the beginning of the present century. This interpretation gave rise to some of the terms used with electricity such as "flow," concerning whose accuracy there is now some question. Franklin's interpretation of the direction of the flow of electricity gave rise to certain statements of laws and rules of thumb which are incorrect in the light of modern interpretation, although some of these are still found occasionally in some of the trade literature of the electrical industry. Teachers and students should be aware of this because it may be confusing in finding discrepancies among various references encountered. The teacher probably should, in so far as possible, guide the student into using references that use the modern terminology.

Lack of Knowledge Makes Assumptions Necessary in Electrical Theory

The assumption that the force of electricity resides

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[1]Duane Roller and Duane R. D. Roller, The Development of the Concept of Electric Charge, Harvard Case Histories in Experimental Science, Case 8 (Cambridge, Mass.: Harvard University Press, 1954), p. 81.

with the electron makes possible many explanations of electrical phenomena, explanations of electrical phenomena, explanations which have utility through many of the branches of the electrical industry. It will account, for example, for the two forms in which ideas of electricity have existed: static electricity, the form known to the Greeks, and current electricity, the form of greater importance to the present. Jones has indicated the differences between the two:

> The differences between static electricity and current electricity are chiefly these: (a) Current electricity usually consists of a fairly large current at a low voltage. Static is very high in voltage (thousands and often hundreds of thousands of volts) but has almost no current. (b) Current electricity will flow steadily and continuously, delivering a regular supply of energy, while static discharges completely in a thousandth of a second, or less. (c) Both the voltage and the rate of flow may be controlled in current electricity, and the energy delivered may be made large or small at will. With static, no such control is possible. (d) All factors concerned in current electricity may be easily measured. Accurate measurement of static electricity is extremely difficult and usually impossible.[1]

It is probable that students will be aware of the two kinds of electricity before they enter the industrial arts shop, because units on electricity in elementary science courses usually begin with static electricity and then concern themselves somewhat with direct current electricity.

Current electricity is, of course, the kind most considered in industry. If electrons can be made to move

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[1]E. W. Jones, Fundamentals of Applied Electricity (Milwaukee: The Bruce Publishing Company, 1956), pp. 5-6.

through a circuit they will carry their force with them to be used as heat, light, mechanical power, or one of the other well known forms of work. Two things are needed to make electrons move to become current electricity: (1) a complete path through which to move (the circuit), and (2) a force to make them move. Dawes indicates why this is true:

> . . . In good conductors of electricity, such as metals, some of the outer electrons are loosely held by the nucleus and are able to move readily from atom to atom. With insulators, the electrons are held firmly by the nucleus, and a relatively high potential difference produces only a small movement of electrons from atom to atom. When electrons are drawn to a body, the body becomes negatively charged. When electrons are withdrawn from a body, the body becomes positively charged.
>
> Under normal conditions, the electrons which are free to move from atom to atom are in a continual state of random agitation which causes them to pass from one atom to another, any electron lost to one atom being replaced by one from another atom. The movement of the electrons being random, there is no general direction of the movement of the electrons as a whole. If, however, a small difference of potential, a few volts, for example, is applied between any two points on a conductor, the free electrons, being negative charges, are drawn towards the point which is at positive potential and move away from the point which is at negative potential.[1]

Electrons Drift Slowly in a Circuit

One aspect of the movement of the electrons that Dawes does not emphasize as much as some other authors is that the electrons drift about slowly from atom to atom even when a current is moving. The current flow results from the

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[1]Chester L. Dawes, Industrial Electricity, Volume I. Direct Currents (New York: McGraw-Hill Book Company, Inc., 1956), pp. 2-3.

voltage, giving a direction to the drift of the electrons from one atom to the next. Annett spends time developing this concept and then says:

> But under normal full load on a light or power circuit, the electron drift is only about 1 foot per hour. Consequently it may require days for the electrons in a long d-c circuit to drift from one end to the other. In an a-c circuit when the voltage reverses 50 or 120 times per second, the electrons cannot drift far in either direction but swing back and forth through short distances in the circuit.[1]

By pointing out that the movement of the electron from each atom to its neighbor takes place simultaneously and almost instantaneously, he continues to explain how the electrons can drift slowly and yet the electric impulse be transmitted with almost the speed of light.[2] Therefore, while each electron would move only the space of one atom, the impulse would move the whole length of the conductor. The electrons in motion which constitute the electric current, then are those which are loosely held by the atomic structure of a copper wire, for instance. The atoms become ions briefly and then pick up another electron to become atoms again as the electric current energizes the circuit. Wires do not seem even to wear out from the electric current itself. In the case of an electrolytic solution a change in the composition actually does take place. As the ions move to the anode or to the cathode

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[1]F. A. Annett, Practical Industrial Electronics (New York: McGraw-Hill Book Company, Inc., 1952), p. 13.

[2]*Ibid.*, pp. 14-15.

and give up or take on electrons (depending upon whether they are negative or positive ions) the ion is converted to an atom of the element which was part of the compound in the original solution. Thus by this process, known as electrolysis, the compound can be broken down into its elements. A current through water will cause it to break down to form hydrogen and oxygen. This is the basis of the electroplating process. All electrolysis requires direct current because the ions must continue to move in the same direction while the electrolysis is going on. Therefore, there cannot be the rapid change in polarity that would result from alternating current.

Mention has been made several times of alternating and direct current. In direct current the direction of the movement of the electrons is constant. If a reversal is desired the attachment of the wires to the source of voltage must be switched or reversed. In most alternating current power circuits the direction of the electron movement is reversed 120 times per second. This means that the voltage rises to a peak and drops to zero 60 times every second in the ordinary 60-cycle residential current. It is obvious that the two types of current would have different properties and therefore different uses. Indeed, some of the importance of this has been pointed out in previous discussions.

The Force for the Movement of Electrons

Related to the concept of the electric charge and of the movement of electrons is the concept of the force which moves the electrons. This is referred to as the electromotive force or E.M.F. This concept rests upon the knowledge that like charges repel and unlike charges attract one another. A condition of balance is continually attempted. It is the degree, for instance, to which a generator or an electric battery can force more electrons to one terminal than exist at the other terminal that determines the energy with which electrons will seek to balance this unbalanced situation and therefore will be a determiner of the rate of the movement of electron in the conductor. The degree of this pressure difference is referred to as voltage, or a difference in potential or electric pressure.

The volt is the unit of measure of electromotive force. By international agreement one volt is the electromotive force needed to produce a current of one ampere through a resistance of one ohm. The latter two terms have been given arbitrary values also by international agreement. Croft lists the following ways by which an E.M.F. can be produced:

1. Electromagnetic induction
2. Heating of contact of unlike substances
3. Chemical action
4. Dielectric fields
5. Friction

6. Vibration or heating of crystals[1]

Electromagnetic induction as a means of producing an E.M.F. is the most widely-used industrially. The production of current by heating the junction of dissimilar metals is another way of producing an E.M.F. which finds use in thermocouples and pyrometers which are useful in the school shop. Chemical action is the source of E.M.F. in the battery or dry cell. It involves a movement of ions in solution. The E.M.F. produced by friction seldom results in industrially useful current flow although considerable potential may be built up. This is the voltage of static electricity. Lightning is, of course, the most vivid example, but the slipping of pulley belts or other conditions where a rubbing action occurs may cause the E.M.F. to develop. The vibration or heating of crystals will produce only a small E.M.F. but this is of considerable importance in microphones and similar equipment.

It is probable that the student in the industrial arts shop will be concerned primarily with the first and third of these methods of producing an E.M.F. to any great degree. However, he should recognize that some of the instruments he may be concerned with and some of the electrical mechanisms that he may use may have their own source of voltage.

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[1]Terrell Croft, American Electrician's Handbook (New York: McGraw-Hill Book Company, Inc., 1942), p. 23.

When an E.M.F. is applied to the input terminals of an electrical device, the device is said to be energized. By use of a voltmeter the electrician can determine the amount of this E.M.F. (voltage) and check it against the specifications on the schematic diagram of the equipment with which he is working. If the reading is incorrect, he will then begin with the terminal of highest voltage and see if he can trace a complete path for the electrons to the point of lowest potential and assure himself that the electrons can perform the intended functions as they pass through the conductor and the various components enroute.

Electrons Are Not Used Up in a Circuit

Students should probably be helped to realize that it is not the electricity--the electrons--that are used up in an electric circuit but the force or voltage. Therefore, it is to be expected that the voltage related to the current returning to the source of E.M.F. will be much less than the voltage as it leaves the source. It is also to be expected that as work is done by the electrical energy, there will be a drop in the voltage. This drop may be an indication of the amount of work accomplished; on the other hand, something may be wrong with the equipment because more voltage is being used than necessary, according to the data for that circuit.

The electrical concepts just presented as examples were selected because they may be of interest to the more capable industrial arts students. Teachers in the field remarked many times that it is this type of student who will take hold and progress through the various difficulty levels of industrial arts electricity.

Discovering concepts which will provide for a wide range of student ability should present no great obstacle for teachers able to become certified to teach industrial arts. In the electrical industry, the level is quickly reached where manipulative activities must be preceded by increasing amounts of theory and "know-how."

Industrial arts electrical activities are characterized by manipulative activity making use of industrial tools, equipment, and techniques. Behind this activity is the ever growing background of electrical concepts which give meaning to the activity. There is a vast electrical literature adaptable to many difficulty levels to aid in background formation.

Summary

The range of activities in the electrical industry is very great. Whenever an electrical job requires adjustment, repair, or improvement, the possession of concepts about the nature and behavior of electricity becomes necessary. To meet this need, the literature of electricity abounds with concepts. Unlike other areas of industrial arts which deal largely with concrete materials such as wood and metal, work in the electrical area deals with an energy which science has not yet been able to explain. Although this energy has not been explained, much is known about its effects, which can be observed in equipment and measured with instruments. Thus, in this chapter, representative concepts appropriate to the one-teacher industrial arts shops were introduced as examples, but not explained at length in view of the fact that excellent treatment of concepts is readily found in the literature of electricity.

CHAPTER IX

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The problem was limited to the objective of industrial arts of helping the student gain an understanding of industry. The study had two phases: (1) to determine the attitude of Iowa teachers of industrial arts toward using the concept approach in teaching of industrial arts to develop an understanding of industry; and (2) to identify from the literature related to the areas of wood, metal, drawing and electricity some concepts that might be developed by industrial arts shop activities.

Summary of the Findings

1. From the visits in the schools, informal discussions and structured interviews with teachers of industrial arts in Iowa, it appears that in the process of development shop work in Iowa schools has taken on two distinct characteristics. The first is specific education aimed at employability and subsequent entry into a trade or industry, an aspect of industrial education with which this study was not concerned. The second is shop activity of a general nature designed to provide a background related to industry for all

of the pupils regardless of their vocation in later life. Among the objectives of industrial arts, the one of assisting the pupil to understand industrial processes can be implemented in the industrial arts shop of the school.

2. Most of the participants appear to realize the effectiveness of capitalizing upon student interest and enthusiasms related to shop work from a motivational point of view. There is also alertness to the danger that hobbies and fads can easily divert industrial arts shop work away from its industrial implications.

3. There is an appreciation of the fact that the total number of areas alone is not necessarily an index of the quality of an industrial arts program.

4. The participants in this study are aware that industrial arts has certain unique functions in general education, just as have other courses. Therefore, industrial arts must integrate its activities with the whole school program so that it can discharge its unique functions effectively.

5. The college teacher-educator participants in the study believe that teaching by the concept method should be encouraged and developed. In addition, they hold that as many avenues for exploration as are feasible in the school shop should be provided for the pupils in view of the expanse and complexity of our industrial society. Furthermore, they tend to agree that the number of areas which should be

attempted is a deeply personalized matter in which the choice of the number of areas must avoid exceeding such limitations as teacher-background, budget, teacher load, etc.

6. The literature related to industry and industrial arts shop work includes a great deal of recipe-type instructions for performing various processes and operations and also includes theory which can be used to form concepts about industry. In the literature examined the proportions of each varied considerably in the four areas studied. Indeed, the literature in the area of electricity which was examined is composed largely of theory which aids in the formulation of concepts, so much so that Chapter VIII had to be changed in approach to prevent needless duplication of already exceedingly well done conceptual material. Representative concepts which the interested teacher could use are given as examples only. In view of this abundance of conceptual material in this area, it was deemed advisable to stress the nature of work in the electrical field and how the industrial arts electrical area could be influenced by it.

7. In contrast, as evidenced in the literature, industrial drawing concepts are actually few, for the bulk of the literature deals with the grammar and techniques of drawing.

Conclusions

1. Teachers should work toward measuring and developing their own skills and background so that they can add areas to interpret industry more completely, especially new areas such as electricity.

2. College teachers, when asked to provide assistance, should provide realistic technical help, as well as policy data and philosophical background.

3. Because many highly valuable aims of general education other than that of understanding industry can subtly influence the unique industrial connotation of industrial arts, shop teachers should be particularly careful that the manipulative aspects are not neglected.

4. High school industrial arts teachers in Iowa are inclined to limit the number of industrial arts areas in their shop to the number they can effectively handle, e.g., (1) woodwork, (2) metalwork, (3) drawing, and (4) electricity. On the other hand, college teacher-educators in Iowa prefer a larger number of areas to provide a better representation of industry and a wider range of experiences for the pupils.

5. Identifying concepts and sharing knowledge is a fruitful procedure. Furthermore, exhibited tolerance of one teacher for another in relation to expressed ideas about concepts should be encouraged.

6. Although they should be made available by means

of bulletins, news letters, or trade journals to act primarily as resources for teachers, it is doubtful if concepts at this time can be feasibly arranged to form a standard course of study which would be universally applicable.

Recommendations for Further Research

1. It is not presently known which areas will produce the greatest number of concepts of industry. Therefore, this problem is in need of investigation.

2. Undoubtedly, certain concepts of industry have greater teaching utility than others in several areas of the industrial arts programs. This is an important problem to be studied.

3. It is not yet known whether physical principles related to science can be identified which themselves can be taught in industrial arts shops instead of the usual areas, such as woodwork or metalwork, in order to understand the activities of industry. Therefore, research needs to be conducted concerning this matter.

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APPENDIX

IOWA TEACHERS PARTICIPATING IN THE OPINIONNAIRE

HIGH SCHOOL TEACHERS

Anderson, Don	Bondurant
Aspenson, M. C.	Mason City
Bader, Lee	Iowa City
Barriger, John	Marshalltown
Behrends, Glen	Waucoma
Bengston, Leonard	Ames
Britson, William J.	Storm Lake
Bro, Ronald	Perry
Broberg, Vernon	Le Mars
Bullis, Reginald	La Porte City
Burnham, Francis	Marshalltown
Burns, E. D.	Fort Dodge
Butler, D. C.	Klemme
Carlson, Dennis C.	Newell
Carlson, Roy A.	Nora Springs
Carrol, James	Waterloo
Chadwick, J. R.	Fort Dodge
Chance, Vernon D.	Britt
Clay, Charles S.	Radcliffe
Cockrum, Dave	Mason City
Crawford, Dwight	Rock Rapids
Dunham, Vernon	Jefferson
Durland, Birney R.	Fonda
Echelbarger, Robert	Eldora
Gatch, Lyle	Spirit Lake
Grandprey, Floyd	Decorah
Hanson, Harley O.	Burt
Hanson, Leon	Elgin
Haynes, Walter	Keystone
Hooper, Stanley	Hartley
Hutzell, Floyd	Cherokee
Jones, Norman W.	West Union
Jones, Robert	Swea City
Ketcham, Walter	Emmetsburg
Lippold, Donald	Waterloo
Long, Ralph E.	Davenport
MacBride, George D.	Ames
Mathews, Vernon	Elma
McCulley, Herbert	Waterloo
McGreevey, Edward H.	Lawler
McKeown, William	Waterloo
Miller, Rex	Ankeny
Mommer, Darrell	Perry
Nahnke, R. J.	Decorah

Nutting, Don	Cedar Falls
Page, Bob	Marion
Palmer, Harold	Mason City
Piersall, Arnold	Cedar Falls
Reinke, Lawrence	Albia
Richmond, Walter	Sheffield
Roorda, John	Neosha
Schill, Frank	Alleman
Schneider, Herbert W.	Ruthven
Schroeder, Bernard W.	Belmond
Scott, M. Robert	Ankeny
Shadle, Owen	Ames
Sharp, Robert	Bondurant
Shearer, A. M.	Spencer
Skinner, Charles D.	Durant
Smalley, Lawrence H.	Cherokee
South, Tom	Perry
VanWranker, R.	Mason City
Wendlent, William	Spencer
Winegarden, William	Waterloo
Yeutter, Wilbur	Hampton

COLLEGE TEACHER-EDUCATORS

Carver, Lowell	Iowa State College
Danne, Eldon	Westmar College
Ditzler, Walter	Iowa State Teachers College
Elliot, Galen	Iowa State Teachers College
Hanson, Russell	Iowa State Teachers College
Hartwell, Frank	Iowa State Teachers College
Hippaka, Tom	Iowa State College
LaRue, James	Iowa State Teachers College
Lathrop, Don	Iowa State College
Palmer, Harold G.	Iowa State Teachers College
Plummer, John	Iowa State Teachers College
Reed, Howard	Iowa State Teachers College
Wagner, Willis	Iowa State Teachers College
Wiener, Merle	Iowa State College
Wright, Lawrence	Iowa State Teachers College

OPINIONNAIRE ON THE CONCEPTUAL APPROACH TO INDUSTRIAL ARTS TEACHING

Items	A great many	A small number	Not significant
1. Do you feel there have been industrial arts activities, procedures, and operations carried on in your shops producing interpretations by your students which will be obsolete in four years or less?			
2. Do you feel there are certain <u>enduring</u> concepts of industrial processes which your industrial arts activities can implement?			
3. Do you feel there are certain concepts of industrial processes which a number of your industrial arts areas can <u>combine</u> to develop?			
4. As time went on, have you found it necessary to discard some activities in industrial arts because they did not help to develop <u>basic</u> understandings of industry within the time limits of your courses?			
5. Has it been your experience that any given areas of industrial arts are <u>superior</u> to others in helping students to develop basic understandings of industrial processes and methods?			
6. Within the time limits of your courses, do you feel that industrial concepts are best developed by having <u>ten or more</u> areas in your industrial arts shops?			

OPINIONNAIRE ON THE CONCEPTUAL APPROACH
TO INDUSTRIAL ARTS TEACHING
(Continued)

Items	A great many	A small number	Not significant
7. Do you feel that industrial concepts are best developed by having five to nine areas in your industrial arts shops?			
8. Do you feel industrial concepts are best developed by having four or less areas in your industrial arts shops?			
9. Do you feel there are important industrial concepts and understandings which will manifest themselves to the pupils through shop activity although this activity is not consciously directed at developing these concepts?			
10. Do you feel there are shop manipulative activities which are irrelevant so far as developing concepts of industry are concerned?			
11. Do you feel there are deeply interesting shop activities which have little value as far as developing concepts of industry are concerned?			
12. Do you feel you have shop activities of great service to other aims of industrial arts but which provide meager development of concepts of industrial processes?			

OPINIONNAIRE ON THE CONCEPTUAL APPROACH
TO INDUSTRIAL ARTS TEACHING
(Continued)

Items	A great many	A small number	Not signifi-icant
13. Do you feel your industrial arts shops should stress an understanding of industry more than the other objectives of general education which it shares with the rest of the school?			
14. Do you feel there are shop activities of a "handicraft" nature which interpret industry enough to merit inclusion in your shop on this basis?			
15. Do you feel the handwork done in your industrial arts gives understanding of industrial <u>production methods</u> commensurate with the time spent on it?			
16. Do you feel manipulative activities give your pupils a more accurate picture of life in industry than does a more verbal approach?			