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Scientific Careers

Vocational Development Theory

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SCIENTIFIC CAREERS

And

Vocational Development Theory

A REVIEW, A CRITIQUE AND SOME RECOMMENDATIONS

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PREFACE

THIS monograph attempts to summarize what research has shown to be the characteristics of natural scientists, mathematicians, and engineers. It evaluates the methods and outcomes of the studies reviewed in the light of current vocational development theory; and it suggests research approaches and emphases which, in the judgment of the Advisory Panel and Staff of the Scientific Careers Project, are most likely to be productive of a better understanding of these and other occupations and of the complex processes of vocational development.

This report will, we believe, be of interest to: (1) those who are concerned with problems of scientific manpower, particularly the identification, selection, and encouragement of potential scientists and engineers; (2) those who are interested in research and theory in vocational development and occupational choice; and (3) students of individual differences and of personality theory who have found that work and occupations provide excellent data for theory testing. It is hoped that this report, the findings and conclusions of which are summarized in Chapter I, will stimulate and guide further work in the study of scientific careers and of vocational development.

In May, 1956 the National Science Foundation invited the senior author to submit a proposal for a project dealing with the identification of scientific capabilities and motivation in scientific career selection. The proposed project was to include:

1. A survey and critical evaluation of information already available as well as studies in progress in the areas outlined, with particular emphasis on science, mathematics, and engineering.

2. An analysis of those areas in which our information seems to be deficient, and recommendations for studies and investigations which serve to round out our knowledge of the subject.

In preparing the proposal, its purpose was broadened so as to place the choice of scientific careers in a suitable theoretical framework. The objective was to emphasize the development of scientific careers and also to view the choice of this kind of occupation against the background of theory and research in vocational development.

Three stages were projected for the research study: (1) a review and synthesis of published theory and research; (2) a meeting of an advisory panel of selected workers in this and closely related areas, focused on this review; and (3) a report incorporating the review and the related work of the panel and staff. The project, known as the Scientific Careers Project, was administered by the Horace Mann–Lincoln Institute of School Experimentation, Teachers College, Columbia University.

A bibliography of pertinent literature was compiled by Mr. John Crites in the summer of 1956, and the review proper was undertaken by the authors in the late summer and early fall. This review of the literature represented the initial phase of the project. In it an attempt was made to find out what is known about the topic under consideration and what we need to know for a more meaningful understanding of the process of vocational choice and development in the sciences.

An attempt was also made to evaluate the literature, to view the research in perspective, and to ascertain trends which might foreshadow the future. This review originally took the form of a working paper, and in revised form supplies the substance of Chapters II, III, and IV of this report. The outline adopted for the review of the literature was suggested by the National Science Foundation's emphasis on the fields of natural science, mathematics, and engineering, as three fields of special interest to the Foundation which are also suitable for an examination of research in professional careers.

The review does not include research studies currently in progress. These studies obviously could not be identified through a bibliographic survey and appeared to require direct contact with such educational institutions and governmental agencies as might be involved in this kind of research. Limitations of time precluded their detailed consideration, and Zapoleon (227) has briefly described them. Nor is this report concerned with an evaluation of the many current action programs in motivation for scientific careers subsidized by the National Science Foundation and other agencies.

In November, 1956, the rough draft of the working paper was forwarded to members of the Advisory Panel. Two other documents were used as background material by the Panel: The Career Pattern Study monograph on *Vocational Development* (196) and the report of the Social Science Research Council Summer Seminar on *Occupational Choice* (18). Each Panel member was asked to write a memorandum, after reading these publications and the working paper, organizing his thinking with respect to what had been done in the study of scientific careers, what we presently know about choice and success in this field, and what the issues in the further study of this topic seem to be. These memoranda were reproduced and distributed to Panel members and served as a basis for a conference at Columbia University's Arden House on December 11–14, 1956.

At the conference each Panel member was invited, initially, to state briefly his point of view as outlined in the memorandum he had prepared after reading the working paper. This statement of position and issues permitted the grouping of Panel contributions along theoretical lines according to the developmental and choice determinants emphasized. One group could be conveniently classified as dealing with the trait-and-factor approach to vocational choice and progress. A second group stressed the impact of social systems on this process. The last group emphasized the importance of personality determinants in the process of vocational development.

Individual Panel members primarily concerned with a particular theoretical approach were then encouraged to elaborate upon their points of view. This series of brief presentations was followed by extended discussion of these points of view in an attempt to clarify further the problems under consideration. The conference then divided into smaller groups based on the differing orientations. These groups prepared summary statements reflecting the positions of each approach. The summaries were read and discussed during the final morning of the conference.

It is this material (the individual memoranda, the conference interaction, and the three summary statements) which has been synthesized in Chapter V of this report. The thinking is basically that of the conference participants. It has been organized, edited, and perhaps interpreted by the authors.

The Advisory Panel was composed of twelve psychologists, a natural scientist, a mathematician, and an economist. To the Panel were added two representatives of the National Science Foundation, one a psychologist and the other an economist, and the two project staff members. The psychologists represented varying theoretical orientations and emphases in their approaches to vocational development: trait-and-factor theory, cultural psychodynamics, a psychoanalytically derived approach, identity and self-concept theory, a theory of interpersonal relations and need satisfaction, and an emphasis on social systems. The economists were familiar with psychological approaches to the problem under consideration, but focused on the realities of the market place and on social systems. The natural scientists brought to bear firsthand experience in the disciplines under consideration. In a sense, then, the Panel represented an interdisciplinary approach to the process of vocational development and career choice.

An expression of appreciation is in order to each member of the Panel: Dean J. W. Buchta of the Department of Physics of the University of Minnesota; Professor Eli Ginzberg of the School of Business of Columbia University; Professor John W. Gustad of the Department of Psychology of the University of Maryland; Professors David V. Tiedeman and Raymond C. Hummel of the Graduate School of Education, Harvard University; Dr. Charles McArthur of the University Health Services, Harvard University; Drs. John R. Mayor and Dael Wolfle of the American Association for the Advancement of Science; Professor Harold B. Pepinsky of the Department of Psychology of the Ohio State University; Dr. Anne Roe of the Veterans Administration; Dr. Stanley Segal of the Counseling Division of the University of Michigan; Dean Dewey B. Stuit of the College of Arts and Sciences of the State University of Iowa; Miss Phoebe L. Overstreet of the Horace Mann–Lincoln Institute of School Experimentation, Teachers College, Columbia University; Professor Albert S.

Thompson of the Department of Psychological Foundations and Services of Teachers College, Columbia University; and Professor Leona E. Tyler of the Psychology Department of the University of Oregon. In addition, the contributions of Drs. Howard J. Hausman and Thomas J. Mills of the National Science Foundation are gratefully acknowledged. This report is in large measure the result of the thinking of the entire Panel. Responsibility for the interpretation and organization of the data and of the Panel contributions remains, of course, that of the authors.

Appreciation is also expressed to members of the Horace Mann–Lincoln Institute of School Experimentation and to members of the Career Pattern Study General Seminar for their critical reading of this report and their constructive suggestions. The services of Mr. William Dubin, a doctoral candidate at Teachers College, as recorder, were most helpful in enabling the authors to reconstruct and analyze the conference proceedings. The typing of the various drafts of the manuscript has been a responsibility of Mr. Alfred L. Webersinn, Mr. David Schneider, and Miss Barbara G. Davis. Editorial assistance has been provided by Mr. Martin Hamburger. Miss Phoebe Overstreet, an available Panel member and colleague on whom we could impose, has provided general and detailed supervision.

Finally, sincere appreciation is expressed to the National Science Foundation, without whose initiative and support this project would not have been carried out.

D. E. S.
P. B. B.

New York, New York
February 1957

CONTENTS

Chapter I

WHAT WE KNOW AND NEED TO KNOW ABOUT SCIENTIFIC CAREERS

THIS initial chapter is a summary of the findings and conclusions of the Scientific Careers Project. It summarizes what is known about the characteristics of natural scientists. It evaluates briefly the methods and outcomes of research in the identification of scientific capabilities and in motivation in scientific career selection. It suggests an integrated approach to vocational development and outlines needed research. The chapter is intended primarily for readers who are interested in the conclusions rather than in the data on which these conclusions are based. It gives the reader an overview of the findings of more than two hundred research studies reviewed in more detail in Chapters II, III, and IV, of conclusions drawn from an evaluation of these studies in Chapter V, and of theory-building trends reviewed in Chapter VI. Readers who wish to follow closely the development of the report may find Chapter I a helpful preview, or they may wish to proceed directly to these chapters, coming back to the final section of this chapter, which deals with needed research, by way of conclusion.

THE NATURAL SCIENTIST

The portrait of the successful natural scientist which emerges from the general literature (reviewed in Chapter II) is that of a paragon. Impressionistic observers describe the abstraction which results as ingenious, curious, and industrious. Biographers use similar terms. The scientist shows a good deal of initiative, is devoted to his work, and has inquiring attitudes and strong inner-directedness. He is enthusiastic, energetic, exceptionally honest, and possesses originality, analytic ability, and powers of imagination and observation. Biological and physical scientists tend to be classified in one broad category called natural scientists. These studies do not seem very helpful in view of the broad occupational groups, the generality of the traits, and the unscientific methods used.

Intellectual Status. The investigations which are more scientific in their methods show that the science student or scientist has intelligence equal or superior to that of the average college student. However, he and his fellows exhibit a rather wide range of intellectual ability. He is capable of rigorous and abstract thinking and of a high level of achievement. Possessed of good verbal reasoning ability, he has a high level of reading speed and comprehension, an extensive vocabulary, and facility of expression.

Superior scholarship is characteristic of the natural scientist. In both high school and college he makes a very good scholastic record, and commonly is in the top 10 per cent of his college freshman class. He earns advanced degrees.

Quantitative Aptitudes. The natural scientist's quantitative aptitudes are superior. His mathematical talent, that is the ability to formulate problems mathematically and to think quantitatively, is generally well above average. A fairly wide range of this ability too contributes to success in science.

Special Aptitudes. The natural scientist generally has good spatial visualization, high mechanical comprehension, superior manual dexterity, and manipulative ability. He possesses such complex mixtures of aptitudes, personality traits, and experience as scientific judgment, originality, adaptive and spontaneous flexibility, and the ability to redefine and formulate problems, to plan, design and conduct an investigation, and to prepare appropriate reports.

Personality. In his personality traits and patterns the scientist appears less of a paragon. He shows self-confidence and an absence of marked feelings of inferiority. He is introverted, shows asocial tendencies, has strong leadership drives, is not conscious of the nature of his motivating forces, and is characterized by late psychosexual development. The scientist is somewhat poorly adjusted socially, suffered from feelings of isolation in his childhood, feels independent of his parents with little discomfort over this, and shows controlled intellectuality and intellectualized emotional energy.

Thus the stereotype of the scientist as a lonely, socially inadequate, and somewhat withdrawn individual, curious, self-disciplined, unemotional, tolerant of others, and intensely devoted to his work finds considerable support in the research literature.

Interests. The future natural scientist's interest in science and mathematics is displayed rather early in life and is relatively constant. This early interest is at first in specific scientific facts or phenomena rather than in science broadly defined. The age ot crystallization of scientific interest appears to range from about ten to fourteen. The age at which scientific interest results in the choice of a scientific career appears to range from about fourteen to twenty.

Family and Social Background. An upward mobile middle-class family background, characterized by favored parental economic, educational, and occupational status, is common among natural scientists in America. The scientist is typically either the only boy or the eldest child. His father is native-born. His ancestry is English, Scottish or Scotch-Irish, or German stock. He may be of either rural or urban origin, and he comes from a northern or western region.

The typical scientist does not appear to be a churchgoer, although his family is affiliated with religious groups which are characterized in America by average or better socioeconomic status and which encourage inquiry, typically those that have long been established in this country. Studies of younger scientists show that the newer immigrant groups (Southern and Eastern Europeans, Roman Catholics, Greek Orthodox, and Jews) are beginning to contribute their share of scientists, suggesting that degree of acculturation may be an important factor.

The general conclusion is that the future scientist tends to come from an intellectually stimulating and well-endowed environment.

Age. The natural scientist does his most productive work at a fairly early age, varying with his field but typically between thirty and thirty-five. However, he keeps on being productive longer than the average man. (Productivity is associated with continuing professional activity, a preference for self-determination of deadlines, and unselfishness of motivation.)

Sex. The general superiority of men over women in scientific achievement is revealed by a few studies, but this difference, like those associated with national origin, may be diminishing as a result of changing cultural factors.

Key Figures and Experiences. Factors perceived as directly influencing the natural scientist to choose this career include key figures, such as the father and high school or college teachers; academic opportunities; and experiences of an educational nature, such as a laboratory project or the reading of certain influential books. The importance of key figures, of exposure to scientific study and experimentation, and of encouragement seems well established.

THE MATHEMATICIAN

The mathematics major and mathematician emerge from the scant available literature surveyed in Chapter III as persons of superior intelligence with superior academic records. Measures of intellectual factors, however, yield only moderate correlations with mathematics achievement. The mathematician appears to come from a superior socioeconomic and cultural background. Religious attitudes and values, or psychological or cultural factors associated with certain religious orientations, have permitted or encouraged an inquiring attitude. Family composition and general interpersonal relationships have been important. Such complex and high-level intellectual traits as originality, flexibility, fluency, sensitivity, and concentration do not appear to be specific determinants of success in mathematics.

The personality structure of the mathematician appears to be that of an objective, somewhat cold and competitive individual in interpersonal relations, with relative freedom from anxiety and affect. But his behavior in social contacts is normal, not eccentric. Much remains to be learned about workers in this field.

THE ENGINEER

In the studies reviewed in Chapter IV, engineers were found to possess general intelligence of a rather wide range, extending from average to very superior. As measured by traditional tests, intelligence is a fairly good predictor of success in engineering school. With respect to verbal intelligence, the range is again extensive—from average to superior. The data suggest that this verbal ability becomes more important to the engineer as he advances in his work. He appears to be a better deductive than inductive reasoner. Traditional tests of verbal ability, such as reading, English, and verbal analogies, appear to be fairly good predictors of academic success in engineering.

Quantitative ability is generally considered to be an essential qualification for success in the engineering curriculum. Tests used to measure this type of aptitude yield correlations with engineering academic success which range from substantial to low. Such variables as general intelligence, reading ability, and spatial visualization have been found in some studies to be more highly correlated with academic engineering success than quantitative aptitude. Perhaps this is caused by variations in curriculum content, ability ranges, and teaching methods.

Engineers rank high in scholastic achievement. Grades and rank in high school, and success in courses in mathematics and science yield fairly high correlations with success in engineering school.

In addition, engineers must have fairly good spatial visualization, although this factor is less important in such fields as sales engineering. Measurements of this aptitude have generally yielded moderate correlations with academic success in engineering. At least average mechanical comprehension appears to be essential for engineers. As in the case of spatial visualization, the relationship of mechanical comprehension to academic success in engineering is significant but not high. Other complex factors, such as analytic reasoning, organizational ability, and ingenious practical thinking, are also mentioned as desirable traits of engineers.

Engineers have been characterized as possessing many general personality traits which lead to success in most other fields of work: tact, interest, initiative, leadership, dependability, self-direction, competence, and energy. They emerge from the more scientifically-made personality studies as stable, self-sufficient, socially conforming, impersonal, introverted individuals, casual but competent in interpersonal relationships.

The interests of engineers appear to be high in the mechanical, scientific, and computational areas and low in the clerical and social service fields. Interests similar to those of successful engineers tend to characterize engineering students. While not highly predictive of success in engineering school, these interests do predict choice of engineering, persistence in training, and stability in an engineering career. The motives given by engineers for choosing their career are liking for this field, desire for security, and felt aptitude for the work.

THE RESEARCH AND ITS MAJOR OUTCOMES

Chapter V is concerned with a detailed evaluation of the literature reviewed in Chapters II to IV. The conclusions reached may be summarized as follows:

> The extensive nature of the literature is impressive, reflecting an awareness of problems in vocational development theory and a widespread interest in the characteristics and development of scientists. However, too many studies have dealt with only a limited number of characteristics presumed to affect the success of college students in science, mathematics, and engineering courses, or presumed to differentiate between curricular groups. Too few are well-designed studies of occupational groups.
>
> Several academic disciplines and methodological approaches are represented, but intellectual factors and generally superficial rather than underlying cultural and personality factors have been stressed.
>
> Theory has not been altogether lacking, although it has not been a major concern. Research has been based largely on trait-and-factor theory, derived from the psychology of individual differences and from a static approach to social factors. Many studies have used this theory only as a source of fragmentary hypotheses, as though the identification of a few specific psychological or social characteristics were an adequate objective. Other theoretical orientations have recently stressed the influence of social systems or have drawn from personality theory.
>
> Some valid measurement tools for use in the identification and selection or counseling of future scientists have resulted from the above approaches.
>
> New developments suggest vitality in this field of research. Emphasis is shifting from a rather static group-differences approach to a more dynamic developmental approach.
>
> Much of the literature is based on subjective and nonquantified observation, such as personal experience and impressionistic biographical study. This nonscientific approach to research on scientists is obviously somewhat incongruous.
>
> Too many studies of science students and scientists report character-

istics so broad and generally desirable as to be of little differential value. When measured characteristics such as intelligence and special aptitudes are dealt with, poor quantitative treatment of data often minimizes the usefulness of such studies.

Too large a proportion of the studies deal with factors related to success in the college study of the sciences, mathematics, or engineering rather than with the determinants of the choice of a career. While success in courses is a prerequisite to and perhaps a determinant of choice, it needs to be treated as such, not as an end in itself. Obviously, not everyone who succeeds in a course enters a related occupation.

It appears questionable whether studies of heterogeneous samples of natural scientists, mathematicians, or engineers can yield maximally useful research results. Studies of more specific fields, such as chemistry, biology, or physics, or, better still, studies of more specific occupations, such as sales or design engineering, physical or biochemistry, applied or theoretical mathematics, would be more rewarding. Further functional subdivisions reflecting level and type of operation would probably yield even richer results.

The criteria of scientific achievement used in many studies seem inadequate. Scientific achievement is too frequently equated with academic achievement in scientific studies. But this is an intermediate criterion whose relationship to ultimate success in the field is not certain.

There is overemphasis on intellectual factors and other easily measured characteristics, but there are too few studies investigating such less easily assessed and quantified factors as personality traits and motivation.

Most research on vocational interests has been concerned with their measurement. With important problems of measurement method solved, the origin and development of interests have recently begun to command more research attention.

Research treatment of socioeconomic variables has been rather one-sided and static. The socioeconomic position of the family is overemphasized and the fluid nature of status is insufficiently recognized.

Most studies are cross-sectional, using statistical prediction methods based on trait-and-factor theory. Factors contributing to vocational success at some one point in time are emphasized rather than the sequence of prevocational and vocational decisions which constitute a career. There is thus a lack of perspective on the dynamics of development viewed longitudinally.

CURRENT APPROACHES

The previous section has presented a very brief critical evaluation of the literature reviewed in more detail in Chapters II, III, and IV. Chapter VI describes new trends in vocational development theory and suggests an integrated approach. These developments are briefly summarized below. The points of view presented are not mutually exclusive, but have a common conceptual foundation with differences of emphasis.

The new look in trait-and-factor theory

Contemporary trait-and-factor theory accepts the emphasis of the classical approach which based much of its research on the theory of individual differences. Much meaningful information with respect to occupational choice and success has been furnished by research on intelligence, aptitudes, interests, achievement, personality, and socioeconomic status. Refinement of instruments, sampling, choice and success criteria, and statistical techniques can continue to contribute materially to our understanding of occupational choice and success. We need more precise data on aptitude requirements, including minimum satisfactory scores for specific fields and levels of scientific and technical work, a better understanding of interests, and better measures of personality, motivation, and attitudes. A functional approach to occupational classification should be developed and applied, particularly with reference to interests and personality traits.

The new look stresses the need for a comprehensive, coordinated, longitudinal approach. It acknowledges the importance of cultural forces and the so-called deeper motives and of the need to understand the entire individual. It recognizes the fact that research advances will result from studying individual traits and factors if these are viewed not only as requirements of particular occupations but also as determinants of a series of decisions at the various stages of a career.

The social systems approach

The social systems approach to vocational development emphasizes the dynamic interaction, over a period of time, of the individual with the social systems which impinge on him, and the interaction of these social systems on one another. The theory is based on the concept of developmental tasks which confront the individual with a need to make certain kinds of decisions and to play certain types of roles. The individual confronted with these tasks is viewed as a member of several social institutions or systems with which he interacts, systems which are instrumental in the making of his choices and decisions. These systems range from the general American culture to specific organizational settings such as the school, family, and church. As one moves from the general culture to the organizational settings, task and rôle requirements change from the abstract to the specific. Essentially, vocational choice is seen as a compromising or synthesizing process of interaction between the individual and the social systems in which he operates. These systems confront him at various age levels with certain developmental tasks and opportunities. It is this interactive process which proponents of the social systems approach stress as affording the basic understanding of the process of vocational development.

Personality theory

Exponents of personality theories emphasize the personality structure of the individual and its dynamic development as the basic determinants of vocational development. This personality structure is commonly seen as the end product of heredity, environment, and experience.

An analytically derived approach uses psychoanalytic theory as a theoretical framework for the study of vocational development, dealing with processes that occur in the normal individual. Opportunities for need gratification are believed to vary from one occupation to another, and even with the levels and fields of an occupation. Job analyses are made to reveal personality demands indicative of differences in the needs which may be satisfied in various occupations. Generally held stereotypes with respect to personality traits associated with specific occupations are also a source of hypotheses which are worth testing.

Researchers who stress interpersonal relations and need satisfaction also view vocational development as a result of the interaction of heredity, environment, and experience. These latter variables assume major importance in this approach, with particular emphasis on early experience within the family and especially on the parental handling of the young child as it relates to need satisfaction. Such variables as parental overprotection or pressure, parental rejection and neglect, and types of parental acceptance (casual or loving) are seen as important factors influencing the direction of vocational activity toward people or toward things. These experiences make for the development of basic attitudes, interests, and capacities which gain expression in the general pattern of life, and ultimately in vocational choice.

The cultural–psychodynamic approach to vocational development emphasizes the interaction of subcultural factors with personality variables. It thus has much in common with several other approaches considered, and is essentially a combination of social systems and personality approaches. Cultural patterns are mediated by the family; the individual is taught from birth. A value system communicated by verbal and behavioral means from parents and peers impinges upon the individual. These values are made one's own and help to determine the choice of a career. Role in the family, adult identifications, and relationships with parents are seen as foundations for later vocational decisions.

The self-concept and identity theory of vocational development views this process as basically the development and implementation of a self-concept. Important problems are: (1) how an individual's perceptions of himself are organized, (2) his awareness of these perceptions, (3) imaginings of the future, and (4) the organizing and possible restructuring of these self-percepts to enhance the likelihood of self-realization. The basic questions in the developmental process are Who am I? and Where do I belong? In this search for identity as it relates to vocational development, stress is laid on the initial importance of the exclusion process, that is, the rejection of occupational fields which the individual considers inappropriate for him. In this process he wittingly or unwittingly limits future possibilities. The importance of such factors as identification, experienced social status, and judgments of one's capacities is stressed.

TOWARD AN INTEGRATED APPROACH

The above orientations are viewed by their exponents as emphases rather than as distinct approaches. They can therefore be synthesized in an overarching theory referred to as vocational development theory. This theory does not treat vocational choice as an event occurring at a point in time and explainable by determinants which can be observed adequately at that same point in time. Rather, occupational choice is treated as a process which takes place over a period of time and which is best explained by a combination of determinants which themselves interact, are modified, and develop with time. This approach may be summarized by a series of propositions:

Proposition 1. Vocational development is an ongoing, continuous, generally irreversible process.

Proposition 2. Vocational development is an orderly, patterned, predictable process.

Proposition 3. Vocational development is a dynamic process.

Proposition 4. Self-concepts begin to form prior to adolescence, become clearer in adolescence, and are translated into occupational terms during adolescence.

Proposition 5. Reality factors play an increasingly important part in occupational choice with increasing age, from early adolescence to adulthood.

Proposition 6. Identification with a parent or parent substitute is related to the development of adequate roles, their consistent and harmonious interrelationship, and their interpretation in terms of vocational plans and eventualities.

Proposition 7. The direction and rate of the vertical movement of an individual from one occupational level to another are related to his intelligence, parental socioeconomic level, status needs, values, interests, skill in interpersonal relationships, and the supply and demand conditions in the economy.

Proposition 8. The occupational field which the individual enters is related to his interests, values, and needs, the identifications he makes with parental or substitute role models, the community resources he uses, the level and quality of his educational background, and the occupational structure, trends, and attitudes of his community.

Proposition 9. Although each occupation requires a characteristic pattern of abilities, interests, and personality traits, there are tolerances wide enough to allow a variety of individuals in each occupation and some diversity of occupations for each individual.

Proposition 10. Work satisfactions and life satisfactions depend upon the extent to which the individual can find adequate outlets for his abilities, interests, values and personality traits in his jobs.

Proposition 11. The degree of satisfaction the individual attains from his work is proportionate to the degree to which he has been able to implement his self-concept and satisfy his salient needs.

Proposition 12. Work and occupation provide a focus for personality organization for many men and women, although for some persons this focus is peripheral, incidental, or even nonexistent. In such persons other foci such as social activities and the home are central. Sex and socioeconomic factors play a part here.

Vocational development is thus viewed as one phase of the general developmental process, subject to the same forces as those which influence the individual's over-all development.

NEEDED RESEARCH

This report has stressed the interactive nature of the process of vocational development: the interaction of personal and environmental factors. Research, then, should reflect this emphasis. It should represent a fusion of the emphases of trait-and-factor, social systems, and personality theories in a broad developmental framework. This fusion can be achieved by means of an interdisciplinary approach, either by teams consisting of members of related disciplines (economists, educators, psychologists, and sociologists), or by individuals broadly enough trained to be able to place the work of their specialties in an adequate theoretical framework. Such an approach should make it possible to avoid the continued production of fragmentary research, and should also provide meaningful answers to the unanswered questions concerning vocational development.

Variables to be studied must be related to a comprehensive theoretical framework; otherwise they will merely add fragments to fragments. With this caution the following problems and topics for research are suggested:

Relationship of the nature of need satisfaction in the family and in other social groups and activities to the sequence of vocational decisions and ultimate vocational choice.

Position in the family as a factor in vocational development. The characteristics associated with the roles of only children, the first-born, and younger siblings in the family, and the relationships between these roles and vocational development.

The formation and implementation of the self-concept as a factor in vocational development. Changes in the self-concept in relation to changed perceptions of occupations, changes in vocational preferences, and occupational choices.

Methods of identifying early interests which forecast later vocational (scientific) interests.

Development of parental, authority, and peer relationships, and the effects of these relationships on vocational choice.

Relationships between role aspirations, role-playing experiences, role concepts, role expectations, and vocational preference and choice.

The process of identification with key figures, both positive and negative, as it influences vocational development.

Vocational choice as the acceptance or rejection of parental or class values, with personality variables controlled.

The nature of the tasks inherent in vocational development and of the related opportunities at the several developmental stages.

The individual's perception of socioeconomic variables, including his status, in the development of vocational preferences and choices.

Psychological and social factors associated with religious affiliation, ethnic group membership, social status, and mobility, and the interaction of these social systems in vocational preference and choice.

Sex roles in vocational development: the self-concepts associated with sex, relationships between sex roles and occupational roles. (That is, an investigation of women physical scientists to determine the traits and factors which influenced their choice of this typically masculine field of work.)

Methods of analyzing and classifying occupations according to personality (need) dimensions to supplement existing aptitude and interest dimensions.

Job analyses refining occupational fields, levels, and specialties to reflect specific functions performed, abilities required, and particularly personality demands.

Criteria of success in scientific work appropriate to the various fields and levels of scientific and technical endeavor.

Better instruments for measuring value and personality factors.

The differentiating traits of workers in specific fields and at specific levels of the natural sciences, mathematics, and engineering. What traits differentiate the biologist from the chemist, the physicist from the mathematician or the engineer? Are there differentiating traits and factors for specialties within a given occupation, that is, botanist as contrasted with zoologist, or embryologist versus physiologist; chemical engineer as contrasted with mechanical or electrical engineer?

Critical minima of aptitudes for defined levels of achievement in the various scientific fields and the identifiable levels within a field.

Factors in interscientific mobility. What types of movement from one scientific field to another take place, and what role do aptitudes, interests, values, and personality traits play in this movement?

Longitudinal studies to reveal more about the development of and changes in aptitudes, interests, values, and needs. (Data collected in current studies of related topics could be exploited for these purposes.)

Traits and factors as determinants of a series of vocational decisions leading to entry into and stabilization in scientific occupations. Choices such as the decision to excel or not to excel in school; to prepare for college, to prepare for work, or to drift through school; to take easy courses or to take challenging courses; to major in one field or in another; and to enter production or to aim at research need to be studied as parts of a sequence.

These, in summary, are the findings and recommendations of the Scientific Careers Project. The basic data are developed in greater detail in the chapters which follow. The recommendations for research are not elaborated upon, since it is our belief that the reader interested in planning research will do so most effectively by studying Chapters V and VI in the light of these summary recommendations.

Chapter II

THE NATURAL SCIENTIST

THIS chapter reviews the literature dealing with the natural scientist in terms of the psychological and sociological variables which have been studied: general characteristics, intellectual factors, personality variables, interests, socioeconomic factors and so forth. It also deals with other complex factors, such as creativity, inventiveness, giftedness, and eminence in scientists, recognizing that they are at once more general than scientific talent but still important. An understanding of these complex general factors may well contribute to insight into the identification of potential scientists and motivation for scientific careers.

GENERAL CHARACTERISTICS

The literature on the natural scientist abounds in studies characterizing the scientist in rather general descriptive terms. He is typically viewed generically, and not considered as one functioning in a specific field of science. Characteristics are ascertained by observation, questionnaires, and biographical methods, and by inferences from these subjectively obtained data. A few such studies are briefly summarized below.

Brandwein (28) noted that future scientists present no disciplinary problems in school, tend to buy books for their own libraries, participate in individual rather than in team sports, engage in self-initiated projects of an intellectual rather than a social type, tend to go to the movies infrequently and to read serious magazines, and tend to be interested in discussion-type activities. Certain general characteristics for which evidence is sought in the Science Talent Search were listed by Edgerton and

Britt (52). These are good work habits, resourcefulness, social skills, cooperativeness, initiative, and responsibility.

In reviewing the literature in this area, Cole (41) listed some of the general characteristics of the scientist: curiosity, industry, initiative, devotion to work, a challenging attitude, inner-directedness, enthusiasm, energy, exceptional honesty, and freedom from restriction.

The following general characteristics of inventors were reported by patent lawyers, research directors, and inventors themselves in a study by Rossman (170): originality, analytic ability, imagination, perseverance, observation, suspicion, optimism, common sense, self-confidence.

Smith (180) characterized the traits of eminent men in various scientific and nonscientific fields as trustworthiness, conscientiousness, a desire to excel, a desire to dominate, self-confidence, self-esteem, capacity to work for distant goals, perseverance, enthusiasm, self-control, dependability, industry, singleness of purpose, initiative, decisiveness, and ambition. The character traits which Hull (99) considered necessary for success in research were self-discipline, courage, tolerance, honesty, generosity.

The traits most frequently found by Shannon (175) in the biographies of renowned research workers in a variety of fields were: enthusiasm, research zeal, resourcefulness, versatility, vision, initiative, ingenuity, originality, aggressiveness, determination, dissatisfaction, industriousness, energy, activity, diligence, perseverance, concentration, attentiveness, application, thoroughness, alertness, curiosity, ambition, desire to excel. Engstrom (58) found that the following traits were considered essential to industrial research applicants: creativeness, scientific training, and ability to work with others in a group.

Conclusion

These terms used in describing scientists refer to characteristics which are so generally desirable (for example, trustworthiness) or so ill-defined (for example, analytic ability) as to be of little differentiating value. Obviously, they would be considered important to success in most of the higher level occupations.

INTELLECTUAL FACTORS

A number of studies report that intelligence is related to success in natural science. The research in this area is treated in terms of general intelligence, verbal intelligence, quantitative intelligence, and scholastic achievement.

General intelligence

Many studies establish a high IQ as indispensable for success in the general field of science. Bloom (19) identified the rapid learner (potential scientist) as possessing a very high IQ. Brandwein (28) believed that science talent is not a specific factor but emerges from high general intelligence, which does not alone guarantee success in science. Cole (41) confirmed the generally accepted relationship of intelligence to achievement in the sciences.

Fields which are reputed to require abstract and rigorous thinking (physics, chemistry, and law) tend, according to Wolfle and Oxtoby (222), to attract students whose intelligence is superior to that of students attracted to the traditionally easier fields. Knapp (100) found that the IQ's of undergraduate science students are slightly but significantly higher than those of students in other fields. Correlations of .408 and .424 were established between Q and L scores of the ACE and college chemistry test scores by Foster (69).

Wrenn (224) investigated the intelligence quotients of Ph.D.'s in the natural sciences, persons who might be expected to go on to do research. He reported their median raw score on the 1937 ACE Psychological Examination to be 106, equivalent to a 1937 Stanford-Binet IQ of about 141. The raw score range extended from 66 to 145 (IQ of 115 to 167).

Smith (180) found that eminence is related to superior intelligence. Comparing eminent researchers with eminent teachers and administrators and the general population, Cattell and Drevdahl (38) reported significant differences in general intelligence in favor of the researchers. In reviewing his work with the exceptionally talented, Terman (199) concluded that the capacity for superior achievement can be detected early in life by a well-constructed aptitude test heavily weighted with the "g" factor.

Guilford (85) found that creativity is bound up with intelligence but extends well beyond this factor, being a product of the total personality. Thurstone (203) appears to share this view. Drevdahl (50) discovered few significant differences in general intelligence between creative persons in art or in science. Wolfle (220) concluded that research eminence covers a wide range of intellectual ability, but can be produced within this intellectual range by interest and persistence. Typically, however, the most eminent come from those making the very high scholastic aptitude test scores.

Roe (164, 165) studied eminent biologists and physical scientists and found relatively wide ranges of intellectual superiority, but a nonetheless high mean IQ.

Conclusion. High general intelligence of a relatively wide range has thus been found to characterize research and scientific workers as well as those who have attained eminence in scientific and other fields. These data often lack precision, partly because of reliance on unquantified observation, and partly because of failure to analyze test scores for critical minimum requirements or in terms of expectancies.

Verbal intelligence

The relationship of verbal intelligence to achievement in the sciences has been studied rather extensively. Brandewin (28) concluded from his experience in the training of "future" scientists that superior verbal reasoning, reading ability, and competence in languages are characteristic. Bloom (19) also stressed high verbal ability, evidenced by extensive vocabulary and facility of expression, as a component of scientific aptitude. However, Terman (200) noted significant differences in the results of two ability tests in language and literature, favoring persons who later became lawyers and medical–biological workers over those who became physical science researchers.

Mean standard verbal ability scores for seven fields of science were reported by Harmon (88), who found that mathematicians and physicists attained scores superior to those of engineers, chemists, geologists, and biologists, but somewhat inferior to those of psychologists and anthropologists. Roe (165) found that intelligence, while a factor in the eminence of physical scientists, was by no means the decisive one. This finding appeared to apply particularly to verbal intelligence, a factor with an extremely wide range of test scores, especially among experimental physicists. Drevdahl (50) reported that creative persons are significantly superior to noncreative persons in verbal fluency, flexibility, and originality. Adams and Mandell (3) found that tests such as verbal analogies, scrambled sentences, reading comprehension, and vocabulary did not contribute significantly to the employment selection of physical scientists.

Conclusion. The studies indicate that a high verbal intelligence with considerable range characterizes scientists, researchers, and creative workers in general.

Quantitative intelligence

The possession of quantitative aptitude is generally believed to be a requirement of achievement in the scientific fields. Subarsky (190) defined one of the components of science talent as the ability to think in quantitative terms. Bloom (19) also characterized the potential scientist as one possessing high mathematical ability.

Stuit and Lapp (189) found that ability in mathematics appears to be more closely related to achievement in college physics than are other factors such as spatial perception and mechanical comprehension. Castore (37) discovered that his mathematics test was the best predictor for screening low from high potential students in chemistry and physics. Brandwein (28) commented on the fact that high mathematical ability characterizes the future research scientist.

The quantitative ability of scientists in seven fields was assessed by Harmon (88), who reported that mathematicians, physicists, and engineers (all with the same mean standard score) were superior in this respect to chemists, geologists, biologists, psychologists, and anthropologists. Mandell (131) found that the Mathematical Formulation Test significantly differentiated research chemists and physicists from other scientists. However, the correlation between this test and the success of employed chemists, using salary as a criterion, was positive but statistically insignificant. A test of college mathematics showed a moderate correlation with ratings of originality in physicists. According to Adams and Mandell (3), the Mathematical Formulation Test was one of the best tests for the selection of engineers for employment, but produced only moderately satisfactory results when applied to chemists, and did not discriminate among physicists.

Conclusion. It may be concluded that superior quantitative intelligence is generally established in the literature as a prerequisite of scientific achievement, particularly in the physical sciences.

School achievement and scholastic factors

A few typical studies are cited to indicate the expected relationship of previous school achievement and other scholastic factors to scientific study, scientific careers, and, more broadly, professional eminence.

The educational influences on the choice of a scientific career by high school girls were studied by Brown (30). She noted that science students had higher mean scores on the arithmetic test, took two science courses rather than one, earner higher science grades, and were generally more capable than nonscience students. Lack of ability was given as a reason for not taking a science course.

Adams and Garrett (2) concluded that articulation between high school work and college physics was relatively poor. Despite this, however, high school records proved to tell more than entrance examination rank about probable success in college physics. A relatively high relationship was found between achievement in college physics and achievement in first-year college work. Hazel and Oberly (95) reported a high positive correlation between students' grades in introductory and advanced chemistry courses. Close agreement also resulted from a comparison of grades in a chemistry and mathematics course. Harmon (88) reported that mathematics and physics majors attained higher mean averages on science grade-point average than engineers, chemists, biologists, geologists, anthropologists, and psychologists.

Wolfle (220) found that 60 per cent of physical science majors came from the top 10 per cent of their college freshman class, whereas the percentage for earth, biological, and agricultural sciences were 52 per cent, 40 per cent and 26 per cent, respectively.

A winners and honorable mention group and a non-winners group in the Science Talent Search was followed up by Edgerton, Britt, and Norman (55). The former group included a greater percentage of science majors, students with superior grades and more extensive education than the latter group. In addition, the former group was characterized by more frequent membership in honorary societies, more frequent receipt of scholarship and fellowship awards, and a larger proportion of students who chose a professional career.

The educational status and needs of a group of industrial scientists in a metropolitan area were investigated by Yeomans, Ober, and Scales (225). They found a general recognition of the value of higher degrees. However, the majority of those with bachelor's degrees only expressed no intention of working toward higher degrees. Educational needs were closely related to one's own field or an allied field of work. Those who were taking courses did not differ from those who were not, with respect to occupational specialty, salary, or educational level.

The relationship between scholastic standing and eminence as reflected by inclusion in *Who's Who* was studied by Knox (111). The higher the scholastic standing, the higher the percentage in *Who's Who.* College graduates included 58 per cent who graduated summa cum laude, 27 per cent magna cum laude, 17 per cent cum laude, and only 10 per cent who graduated with no honors. Graduation honors proved to be a better predictor of inclusion in *Who's Who* than extracurricular achievement.

According to Van Zelst and Kerr (207), technical and scientific productivity was characterized by a history of more academic degrees and higher rank. Visher (211) investigated the value of academic training as judged by leading scientists. About one-third felt that high school training contributed little. About two-thirds said college training was valuable. Nearly all attached value to graduate training. About half had had post-doctoral training, and 85 per cent of these considered it highly beneficial.

In his study of gifted men, Terman (200) found that the top groups in earlier scholastic achievement in both high school and college were the adult physical science researchers and scientists in the medical–biological fields, as contrasted to engineers, physical and biological non-research scientists, social scientists, lawyers, and men engaged in the humanities.

Conclusion. The scientist and science major clearly emerge from the literature reviewed as superior scholars whose good grades in high school tend to be indicative of good grades in college, which in turn tend to predict success as an adult scientist.

SPECIAL AND COMPLEX SCIENTIFIC APTITUDES AND ABILITIES

The literature deals rather extensively with such well-recognized special abilities as spatial and mechanical aptitudes, and with others more complex and less easily identifiable as they relate to the field of science. Some of these, also clearly saturated with intellectual components, are treated here because of their complexity.

SPATIAL AND MECHANICAL FACTORS

Stuit and Lapp (189) found that the spatial relations factor, as measured by the Minnesota Paper Form Board, does not correlate highly with success in college physics. These authors also reported that an understanding of mechanical movements does not bear a close relationship to success in college physics. This finding is not concurred in by Subarsky (190), who identified mechanical-mindedness, and also manual dexterity, manipulative ability, as components of science talent.

Low correlations between a surface development (spatial) test and the success of employed chemists were reported by Mandell (133), using salary as a criterion. Again the data disagree with opinion, for Rossman (170) reflected the self-characterization of the inventor as including mechanical ability. He also stressed the ability of the inventor to recognize industrial problems and needs, and his possession of native ingenuity to satisfy these needs. In her study of scientists, Roe (165) found that theoretical physicists obtained scores on a spatial test superior to those of other scientists. This suggests the value of studying more refined occupational categories. The range was rather wide, however, in all scientific categories and the test was negatively correlated with age.

Terman (200) reported that a high mechanical ingenuity rating by parents and teachers distinguished his gifted science from his gifted nonscience group, and that the highest mechanical abilities (as assessed by parents) distinguished scientists from nonscientists. Some spatial tests, such as surface development, produced fairly good results for selecting engineers, and other tests, such as block-counting and cube-turning, had some validity in work by Adams and Mandell (3).

Complex abilities

Adams and Mandell (3) found that a figure-analogies test produced moderately good results in the selection of research engineers, but poor results when used with chemists and physicists. The only test with positive results for all three groups (physicists, chemists, and engineers) was the Hypothesis Test, which assessed the ability to evaluate the relationship between facts and hypotheses and the relationship of hypotheses to the exploration of physical phenomena. These authors also found that science judgment as measured by a test of scientific methodology and evaluation yielded moderately good correlations with ratings of chemists and physicists, but was unrelated to ratings of engineers.

In his study of federally employed chemists, Mandell (133) obtained a significant correlation between a scientific hypothesis test and salary. Flanagan and his associates (67) established the following rather complex basic requirements for research personnel by the analysis of critical incidents in research: formulation of problems and hypotheses, planning and designing the investigation, conducting the investigation, preparing reports, interpreting research results. In addition, the following nontechnical requirements appear to be critical: administration of research projects and the acceptance of personal and organizational responsibility. Roe (166) found that biologists and experimental physicists tend to use visual imagery to a considerable extent, whereas theoretical physicists characteristically employ verbal or other symbolizations.

Imagination, analytical power, and curiosity were listed by Hull (99) as components of research ability. Van Zelst and Kerr (208) attempted to ascertain the nature of technical and scientific productivity by the cluster analysis of traits. Three clusters—creative ability, opportunity for exploitation of training, and industriousness—were isolated from fourteen variables previously studied. The authors conclude that high scientific and technical attainment is basically "the industrious application of creative ability to opportunity." Davis (48) listed the following as characteristic of the scientific attitude: concept of cause and effect, ability to distinguish between fact and theory, and habits of judgment based on fact rather than on prejudice.

In describing creativity, Murphy (148) listed a sensitiveness to a specific form of experience—usually sensory—and an ability to manipulate sensory experiences so as to restructure relationships and improvise new ones. Gamble (75) discussed the characteristics of research workers and listed the following as critical: ability to set up a problem, to find a tentative solution, and to validate it. Guilford (85) analyzed creative thinking into originality, redefinition, adaptive flexibility, spontaneous flexibility, and sensitivity to problems. Brozek (31) concluded that successful research does not require, in a large percentage of jobs, a remarkably discerning and original mind. Success depends largely on good judgment with reference to selection of and attack on problems, and on experience in the organization and execution of research operations.

Conclusion

Scientific talent, inventiveness, and creativity appear in most studies to be correlated with such special and complex aptitudes as mechanical comprehension, spatial visualization, originality, flexibility, sensitivity to problems, and ingenuity, particularly when the object of study is scientists rather than students in science courses.

PERSONALITY FACTORS AND CHARACTER TRAITS

The relationship of personality to choice of and success in science as a career has been widely considered. About one-third of the surveyed studies of natural scientists are devoted to this variable, totally or in part. They range from psychologically unsophisticated observational and introspective studies of personality to the more sophisticated (though often no more quantitative), techniques of personality assessment. The classification of some of the traits studied is not sufficiently precise. Some personality traits strongly suggest intellectual qualities, just as some of the more complex intellectual or special aptitudes suggest conative and affective characteristics.

Using self-descriptions, Gough (81) studied the relationship between certain personality factors and high school achievement and found the following to be characteristic of the more successful: optimistic self-confidence, self-control, capacity for sustained and diligent application, orderliness, resourcefulness, seriousness of purpose, acceptance of others, denial of ill-will and animosity, absence of interpersonal friction, personal efficiency, vitality, and integration.

With gifted high school and college students, Gough (82) concluded that the basic difference between achievement and underachievement is due to socialization as opposed to asocialization. Achievement among the gifted is a form of social behavior.

On the basis of work with talented high school students, Brandwein (28) listed as factors predisposing to a research career the traits of persistence and questing, that is, a dissatisfaction with present explanations of aspects of reality. He reported that future scientists give, as high school students, a picture of introversion rather than extroversion. Subarsky (190) and Foshay (68) suggested that curiosity tends to lead to scientific inquiry, and Foshay concluded that the former trait arises in children with sound emotional foundations.

In a study of nonintellectual factors which influence scholastic achievement, Terman (199) concluded that emotional stability, persistence of motive and effort, confidence in abilities, and strength of character were important factors. Motivation to achieve has been studied experimentally by McClelland and associates (142). The data strongly suggest a positive relationship between achievement motivation and emphasis on independent individual development in the family.

Krathwohl (116) postulated a general theory of work habits of industriousness. Industriousness appeared, however, to be specific rather than general, indolence in one field not being an index of indolence in another.

MacCurdy (127) used a personality questionnaire to study superior science students in college and found that they displayed self-control, self-discipline, a desire for leadership, and somewhat asocial tendencies. They were, in addition, curious, materialistic, and persistent. Hull (99) observed similar traits in industrial research workers.

The personality correlates of undergraduate fields of specialization were contrasted by Teevan (197) by means of the Blacky Pictures. He found that the science division had the lowest disturbance scores on all categories. Knapp (108) used the TAT, Rorschach, and Blacky Pictures to investigate the nonintellectual determinants of scientific interests. TAT stories of the science group were judged lowest in dramatic saliency, were consistently rated lower for manifest aggression, least frequently had patterns of overt solution to the conflicts in the stories, and were more frequently left without solution or with an ambiguous solution than those told by social science, literature, and humanities students. In addition, where clear solution patterns were offered, those of science students showed the highest ratio of repression rather than overt solution, and the lowest incidence of hostility of father or father-surrogate. Finally, science students were least likely to submit stories involving either acute debasement or marked moral vindication of the principal character. The Rorschach Test administered on a group basis did not differentiate significantly between the three groups. On the Blacky Pictures, science students scored lowest on disturbance, on the oral-erotic and sadistic level, and in the Oedipus conflict area. They showed the least disturbance with respect to guilt feelings and scored lowest on the over-all disturbance score.

Raskin (157) compared scientific and literary men, and found that the former are characterized to a greater extent by emotional stability.

Reviewing earlier writings on eminence, Smith (180) found extreme depression, liability to anger, and unemotionality to be some of the characteristics of an extensive, although sometimes inconsistent list. Also striking a discordant note with somewhat inadequate data, in an examination of the problem of genius, Lange-Eichbaum (120) contended that 90 per cent of all those called geniuses demonstrated "more or less severe psychopathic states," and that in 12 per cent there was explicit psychosis. In another a priori analysis of creativeness, Murphy (148) concluded that certain factors produce nervous wear and tear on the creative person. These are intense craving, being out of context with most of his environment, self-engrossment, and inevitable frustration, which Murphy felt were possible explanations of what he considered the nervous instability of genius.

It is noteworthy, however, that more objective approaches contradict such conclusions. Thus Terman (198) compared the characteristics of the 150 each of the most successful and the least successful of the gifted men he first studied when they were children. Success was defined in terms of educational and vocational achievement. He too found that personality factors were extremely important determinants of success. But the successful group was characterized by a more complete integration toward its goals, greater perseverance, more self-confidence, and absence of marked feelings of inferiority. The successful group, further, had a record of fewer military psychiatric rejections.

Creative scientists were rated considerably less self-sufficient and radical than creative artists or noncreative individuals in a college population studied by Drevdahl (50). But in this study also the science group was significantly more stable and controlled, less sensitive emotionally, more secure and less tense than the arts group. The scientists were also found to be less bohemian and egocentric than the arts group.

In an a priori discussion, Kubie (119) points up the need for socioeconomic and psychoanalytic investigations of some unsolved problems of the scientific career. He emphasizes the many conscious and unconscious forces whose interplay presumably determines the choice of this kind of career. He suggests psychoanalytic study of promising young men who plan to become scientists, of men who have functioned in the field for years, of highly endowed but unproductive scientists, of creative men who have ended in despair, and of the most successful.

Experience with employed scientists led Krugman (118) to conclude that they needed recognition, had a need to be kept informed, needed to be permitted to follow through on jobs they start, needed facilities to accomplish their work, wanted to be relieved of red tape, and expected management to encourage their professional affiliations. Shapiro (176) investigated the job values of scientists. She found that interest in the work, working conditions, earnings, and opportunities for advancement were the basic reasons for staying on or leaving a job. Other factors, such as personal considerations, security, the war effort, and pursuit of graduate studies, were less important.

In Cattell and Drevdahl's (38) study, personality inventories administered to eminent researchers revealed outstanding professional and academic scientists to be different from the general population. The scientists possessed traits characterized by Cattell as greater ego strength or stability, dominance, desurgency, lack of group superego, adventurousness, sensitive emotionality, lack of paranoid trends, and lack of free-floating anxiety. They differed from the university undergraduate population (with corrections for age) by being decidedly more schizothymic, self-sufficient, desurgent, radical, probably more paranoid, and possessing higher somatic anxiety. Researchers, when compared to teachers and administrators, were more schizothymic, more self-sufficient, emotionally unstable, bohemianly unconcerned, radical, dominant, and paranoid.

Terman (201) attempted, by studying 800 men of his original gifted group, to differentiate between scientists and nonscientists. Scientists tend to score lower than nonscientists on social relations, with traits of loneliness, shyness and slowness in social development.

Using a self-assessment technique with employed industrial scientific personnel, Van Zelst and Kerr (209) found productive scientists to be original, not contented, not conventional, imaginative, curious, enthusiastic, not impulsive. To a lesser degree they were self-confident, free from worry, not inhibited, not formal, subjective, fastidious, not acquisitive.

In a study of 250 renowned research workers Shannon (175) listed the following traits commonly appearing in the biographies of natural scientists. The scientists were enthusiastic, creative, aggressive, determined, dissatisfied, industrious, persevering, attentive, thorough, alert, curious, ambitious, self-confident, and tolerant. In his study of inventors, Rossman (170), using questionnaires, ratings, and self-ratings, stressed the inventors' astonishing persistence of motive and effort. Myers (149) characterized the distinguishing traits of the research worker as more academic than worldly, introverted rather than extroverted, and those of the routine scientific worker as placid, steady, and patient.

Intensive psychological studies of small groups of eminent scientists were made by Roe (164, 165, 166), using interviews, the Rorschach, and TAT. She also used the Group Rorschach to study university faculty members in the same fields. The biologists were not characterized as a group by a completely consistent personality pattern. Biologists at individual institutions showed, in some instances, striking differences from those in others, with further suggested differences among different fields of biology. Certain personality trends appeared with fair consistency. Biologists are sensitive to aspects of a situation not generally noticed. They are somewhat egocentric, have good control, and are discriminating. Their interpersonal relations are superficially smooth, if not warm. They are unaggressive, not outgoing, and would not rate high in masculinity. Like other scientists, they display a persistent and intense devotion to work. Late psychosexual development appears to be another common characteristic. Many of these personality characteristics also describe natural scientists in general: late psychosexual development, somewhat poor social adjustment, childhood feelings of isolation, feelings of independence from parents and lack of guilt over this, controlled intellectuality and intellectualized emotional energy, and almost complete absorption in their work.

Roe (165) further noted differences between theorists and experimentalists. The former showed greater awareness of personal problems and a more controlled handling of anxiety. Differences were also found between biological and physical scientists on the one hand, and social scientists (anthropologists and psychologists) on the other. Natural scientists were more independent of parental relations than social scientists, showed greater anxiety, lacked interpersonal interest, and depended on visual rather than verbal imagery.

The points made at a 1953 conference on nonintellectual determinants of achievement were reviewed by Smith (181). He reported the conclusion that personality and sociological and psychological factors of motivation appear to be variables neglected by researchers. Suggested at the conference as fruitful research variables were college adjustment, social sensitivity, social mobility, religious factors, and family interaction patterns. Problems of research strategy were also discussed. The Productive Behavior Research at Ohio State University under Pepinsky (152) and associates is attempting, among other things, to determine the individual characteristics of students assumed to be capable of superior academic performance and to construct a measure of drive toward achievement.

Conclusion

The picture of the natural scientist which emerges from the above research is that of a person whose relationships with others, both in the family as a child and later as an adult, are superficially smooth but lacking in warmth. His social development has been slow and limited, so that he appears somewhat lonely as a child and as an adult, unaggressive and introverted. He is rather independent of his parents, shows little hostility toward his father, views his independence rather calmly and without guilt, tends to repress rather than to seek overt solutions for what feelings he does have. Despite this somewhat negative picture, the successful scientist is a socialized individual, one who has accepted many of the values and goals of his culture. He is also an emotionally stable and self-confident person. He is goal-directed, achievement-motivated, controlled, planful, persistent to a high degree, and curious or questing.

This general characterization appears to hold rather well for various types of natural scientists, who in many of these respects are different from social scientists and humanists. There are some indications of significant differences between persons in the various fields of natural science, and between persons in the specialties within a field, but these have been little explored. These specialty differences, the nature of interpersonal relationships in the childhood family, and the origins and measurement of motivation appear to be especially fruitful fields for further study. Roe's work points up some possibilities of these types, and has led to further theorizing in Chapter VI.

INTEREST FACTORS

Interest might on theoretical grounds have been included in the section on personality. However, the literature in this area seems sufficiently broad and this type of trait sufficiently different from those discussed under personality to warrant treatment in a separate section.

High school students who become scientists were studied by Brandwein (28), who detected early, varied interests. Sports, music, general reading, and art were of importance equal to science. Fewer than half of the Science Talent Search winners studied dated their interest in science prior to age fourteen. A somewhat higher percentage indicated that their interest had developed sufficiently by the time they had reached second-year high school to warrant thinking of science as a major choice. The opportunities available for exploration of their interests appeared to be helpful in choosing the field of science. Brandwein suggests that early interest in science is a cultural factor. He stresses, however, that this interest is not commonly sustained, emphasizing that no clear relationship exists between scientific interests in the ninth grade and developed aptitudes in science.

Mallinson and Van Dragt (129) compared Kuder scores at the ninth and twelfth grades in an effort to determine whether the interests of high school students in science and mathematics stabilize during the high school period. The authors concluded that interests which are high in the ninth grade are likely to be high in the twelfth. However, the assumption that the score will remain the same is not valid. Over-all predictability is not high, judging by correlations of scores or rank in grade nine with those in grade twelve. The study, furthermore, fails to substantiate the claim that interest is likely to be a reliable predictor of achievement in these areas.

In a study of the relationship of socioeconomic factors to the inventoried vocational interests of senior high school students, Erlandson (60) suggested that home and family background might be the most important determinants of vocational interests.

Evidence to this effect is provided by Jordaan's thesis (105). He found that high school boys who excelled in mechanical comprehension, as measured by the Bennett Mechanical Comprehension

Test, tended to have scientific, technical, or mechanical interests on Strong's Vocational Interest Blank, regardless of social status. This was true except in the case of sons of executives, who tended to lack scientific, technical, or mechanical interests. Similarly Hyman (100), reported intelligence related to Kuder interest scores only when socioeconomic factors were controlled, scientific interests being a characteristic of middle-class high school boys of superior intelligence.

Working with college students followed into adulthood, McArthur (136, 140) has further shown that vocational interest inventories are better predictors of occupational choice in middle-class students than in upper-class students, presumably because of an emphasis on self-realization in the middle class, while following the family tradition is important in the upper class.

The early science interests and activities of adolescents were investigated by a questionnaire method by Zim (228), who reported that at this developmental stage interest in science is related to specific items and things. He found an uneven distribution of scientific interest: biology and physics items are of interest, whereas geology, chemistry, and astronomy are not. Out-of-school activities are potential sources of science interest, whereas school subjects appear to have no important effect on these preferences. Science interests gradually change with age within the secondary school, Zim noted (229). Average age of first interest in science was about ten. First interests were chemistry sets, electricity and radio, motors, and first aid. Persistence of interest in the same or related areas and in achieving immediate and ultimate goals (completion of course or degree and a specific career in science) was also characteristic of these adolescents. Thompson and MacCurdy (202) reported that first interest in the sciences can be identified between the ages of seven and twelve, and found a definite relationship between first interest in science and occupational choice. Examining the background of eminent scientists by the interview method, Roe (165) observed that scientific interest did not crystallize before high school, but when it did, it was generally on the basis of a science course.

Experience with science students led Bloom (19) to note that a scientific hobby characterized the potential scientist. In his questionnaire follow-up of the Science Talent Search winners and other high general ability college freshmen and sophomores, MacCurdy (127) found that the interests of superior science students were usually concentrated in one or two well-developed areas requiring intellectual, mechanical, or scientific activity. Such interests as high fidelity, crafts and carpentry, repairing mechanical things, photography, nature, and science were common.

Givens (78) investigated the extent to which success in college science courses could be predicted from Kuder Preference Record scores. He concluded that Kuder scientific interests and grades in college science are not closely related.

The relationship between student preferences (as measured by the Kuder) and the divisional choice of study of college students in their junior year was studied by Yum (226). He found clear and consistent group profiles. Both physical and biological science groups scored significantly higher than social science groups on Kuder scientific interests, while the latter groups scored higher in literary interests. Nonsignificant differences were found between the physical and biological science groups.

Strong's long-term and intensive studies of interests (186, 186a) had already established the stability of inventoried interests, their ability to differentiate occupational groups, and their predictive validity when occupational choice and stability are the criteria. The inventoried interests of physicists and mathematicians are very similar, and closely resemble those of chemists and engineers. They also resemble those of persons in the biological sciences, but somewhat less.

In his longitudinal study of scientists and nonscientists in a population of gifted men, Terman (200) found that physical science researchers, engineers, and medical–biological workers scored highest (on the Strong Vocational Interest Blank) on interest in science and mathematics. Early interest in science was found to be far more common among these groups than among the nonscience group. The physical science researchers scored highest on interests in the scientific fields and, like engineers, scored lowest in the literary and social service fields. The science group had a high mean masculinity score, whereas the nonscience group had a low score. Terman noted the high degree of constancy of interests as shown by agreement of early manifest interests with Strong's Blank results for adults.

Conclusion

The literature on scientific interest shows that this type of interest develops relatively early in life; that extremes of socioeconomic status tend to inhibit or prevent the development of interests which are appropriate to scientific aptitudes; that scientific interest is characterized initially by interest in concrete things or activities and is relatively stable; that successful science students show interest profiles similar to those of successful workers in science fields; that the various fields of science have distinctive but related interests; and that interests, while not predictive of success in these fields, are predictive of occupational choice and stability.

SOCIOECONOMIC, CULTURAL, RELIGIOUS, AND FAMILY FACTORS

Many studies have attempted to examine the relationship between socioeconomic status, family factors, religious variables, and scientific careers.

Socioeconomic status

The common belief that eminent men are characterized by superior economic status, social position, educational background, and parental occupational status was supported by Smith (180). The largely professional background of the fathers of starred scientists in *American Men of Science* was reported by Visher (211). Norman (150) found that his honors group among the science talent contestants had a significantly higher percentage of professional fathers.

The physical science researchers in Terman's (200) gifted group had the highest percentage of fathers who were college graduates and employed in the professions. On the whole the medical–biological group and the physical science research group had the most favored family background. Engineers and physical and biological nonresearchers had the least favored backgrounds, with social scientists, lawyers, and those engaged in the humanities holding an intermediate position. Edgerton and Britt (54) found correlations ranging from .38 to .59 between the regional productivity of Science Talent Search winners and certain economic and educational variables, such as educational expenditure per pupil, lack of educational deficiencies, per-capita income, and per-capita telephones.

Raskin (145) also had similar findings in her biographical study of eminent scientists and men of letters of the nineteenth century. The majority of gifted men came from the three highest socioeconomic levels, with the professional level making the largest contribution. MacCurdy (127) substantiated the favored parental background of the superior science students he had studied, and Davis (47) found that the lower the social origin the smaller is the probability of attaining eminence.

A lower middle-class origin was most characteristic of the American scientists studied by Knapp and Goodrich (109), while Roe (165) reported a characteristically middle-class, professional background for eminent scientists. Erlandson (60) found that socioeconomic factors such as parental occupation, parental education, and source of family income were related to primary scientific interest patterns, and Hyman (100) supplies similar evidence.

Raskin's (145) and Knapp's (108) studies showed that despite typically middle-class professional backgrounds, parents of science students and scientists are more frequently engaged in other than white-collar occupations and much less frequently in executive or professional work than social science and humanities students or literary men. Harrington (89) found that the "A" students in science tend to come from the upper-middle socioeconomic level (28.3 per cent of them from professional classes). McArthur reviewed studies of the relationship of socioeconomic origins to achievement in the highly selective Eastern colleges (137). These studies agree that the upward-mobile middle-class boys who attend such institutions tend to make better grades than boys who come from upper-class homes. The former, in Kluckhohn's terms (107a), have a "doing" orientation, whereas the latter have a "being" orientation. The former look to the future, the latter to the past. The latter follow in their ancestors' footsteps, the former aspire to become ancestors.

The predominance of Puritan, other English, German, Scottish, and Scotch-Irish stock among the starred scientists in *American Men of Science* was noted by Visher (211), and Terman (200) reported that his physical science research group had the largest percentage of American-born parents. Cole (41) supports the general picture of the family background described above in his review of the characteristics of the scientist.

Conclusion. The upward-mobile middle-class origins of American scientists, as well as their favored parental background, are emphasized in most studies. However, it is well to point out that trends do not indicate a monopoly.

Geographic factors

Urban regions with a relatively cool and dry climate were found by Smith (180) to be more favorable to eminence as places of birth and rearing than other geographic areas. More than half of the leading American scientists in Visher's study (211) lived in cities when young. Some 27 per cent were born in the East North Central States, 26 per cent in the Middle Atlantic States, 21 per cent in New England, and 12 per cent in the West North Central States. Visher (212) concluded from a biographical study of great men that regions comparatively poor in resources come in time to be peopled by those deficient in ambition, and are hence less productive of eminent persons.

In another early study of starred and non-starred scientists in *American Men of Science,* Poffenberger (156) found that there were no significant differences in urban versus rural origin. He also reported an uneven distribution of their geographic origin, with the South Atlantic, South Central and Pacific regions having a relatively small proportion of these men. The North Atlantic and North Central States appeared to be the most productive regions. Knapp and Goodrich (109) more recently confirmed the scientific fertility of the Midwest, raised the Far West to an equally high position, and found non-urban areas most productive.

Conclusion. There is contradictory evidence concerning the urban or rural origins of scientists. But it does seem clear that they come most frequently from North Central or Western regions of the United States, and less frequently than formerly from the North Atlantic States.

Educational factors

Study of the collegiate origins of scientists and scholars reveals interesting differences. Knapp and Goodrich (109) found that the production of scientists was inversely related to size and to "vocationalism of curricular emphasis." Small liberal arts colleges strongly committed to general education were the most productive institutions. Universities were less productive of scientists, and engineering institutions were inferior in this respect. Institutions of either high or low cost were less productive of scientists than middle-cost institutions. Productive institutions, furthermore, were characterized by a lack of preoccupation with social life and intercollegiate athletics.

Knapp and Greenbaum (110) made a study covering all scholarly fields in the more recent years of 1946–1953, a period in which the education of many students was subsidized by the GI Bill. They found that fellowship and Ph.D. recipients from universities were clearly more inclined to enter the field of science than were those from liberal arts colleges. The most expensive institutions were several times more productive of graduate scholars than those of middle or lowest cost. But recipients of fellowships and doctorates from high-cost institutions were less inclined to pursue the sciences and more inclined to enter the humanities. Educational institutions of consistently high productivity in scholars were found to be located in New England and the North Central States. However, recipients of fellowships and doctorates from New England institutions tended to enter the humanities rather than the sciences, whereas those from the Southern and Western regions showed a high proclivity for science.

Conclusion. The two Knapp studies suggest that some changes may be taking place in the collegiate origins of scientists. However, the middle-cost institutions which do not stress social life or athletics are consistently the most productive.

Religious factors

Davis (47) found that the ratios of eminent persons from different church groups varied directly with the socioeconomic level of the religious denominations. Lehman and Witty (125) reported that Protestant denominations generally produce several times their expected quotas of scientists (depending on denominational affiliation). Jews supply about the expected quota and Catholics only a small percentage of their expected quota. In a study of scientifically talented boys, Norman (150) noted a highly significant deficiency of Catholics and a significant excess of Jews in the honors group. Visher's study (211) of the origins of American scientists showed a predominantly Protestant background. In a study by Knapp and Greenbaum (110), privately controlled, nondenominational educational institutions were consistently very high in the production of young American scholars, educational institutions of Catholic affiliation appeared to be uniformly low, and public and Protestant institutions occupied a middle ground.

Roe's (168) study of 64 eminent physical scientists noted that five came from Jewish homes, and all but one of the rest (a free thinker) came from Protestant backgrounds. She suggests that in the United States, Catholics rarely become good research scientists. Generally, too, scientists are not an active churchgoing group.

Knapp and Goodrich (109) found that careers in science were characteristic of students with liberal Protestant affiliations. However, no significant differences in religious affiliations among groups of natural science, social science, and humanities students were found by Knapp (108).

Conclusion. In the United States Protestantism and Judaism have tended to produce more scientists than Catholicism. However, in view of Davis' (47) findings on the relationship of the socioeconomic level of the religious denomination to eminence, Knapp's (108) recent failure to find religious differences among science and nonscience students, and the gradual socioeconomic upgrading of the more recent non-Protestant, non-Anglo-Saxon elements in the population of the United States, it seems legitimate to conclude that the differences in the religious affiliations of scientists and nonscientists, the eminent and the less eminent, will be less important than formerly.

Family structure

Terman (200) found that among his gifted men, the physical science research group had the lowest percentage with two or more siblings. In a study of Rhodes scholars, Apperly (7) determined the predominance of the only son. In larger families, however, there was a tendency for the scholar to be the youngest child. Roe (168) saw a tendency for eminent natural scientists to be first-born children. In addition, the biologists studied tended to have lost a parent at an early age. MacCurdy (127) also notes the frequent status of the scientist as a first-born child with no brothers. McArthur (138, 139) has shown that the first child is adult-oriented, serious; that when self-reliant, independent, and undemonstrative (as first sons tend to be), he is likely to adopt some role model advocated by the mother who enables him to bypass or surpass his father. In the middle class of a generation ago, with few scientist-parents, this led to achievement in science.

Conclusion. The scientist emerges from the literature as typically an only or eldest son.

BIOSOCIAL FACTORS

This section is devoted to such biological and biosocial factors as age, aging, sex, and physical build in relationship to vocational development and the choice of a scientific career.

AGE OF VOCATIONAL DECISION

The scientists Visher (211) studied decided to follow this vocation relatively early in life. About a quarter decided before they were fifteen; more than half decided before entering college, and almost all (nine-tenths) decided before college graduation. Terman (200) found that physical research scientists more commonly than other gifted men began consideration of their life's work before they were sixteen, and chose the occupation that was first seriously considered.

Roe (165) showed that physicists decided to enter this field at about their junior year in college. Zim (229) pinpointed the average age of first interest in science at ten years, six months. Brandwein (25) found that only 24 out of his 52 future scientists felt that their interest in science went back before age fourteen.

Conclusion. The bulk of the evidence thus supports Cole (41), who concluded that the scientist is characterized by an early commitment to this field.

Age and productivity

Clague (39) studied the aging problem in research workers and found that a larger percentage of middle-aged to elderly men are retained in the research-science field than in occupations in general. Some 38 per cent were between the ages of forty-five and sixty-four. The author concluded that this type of ability does not decline appreciably before the sixties, hence the higher average age in these occupations.

The aging process is characterized by Shock (178) as gradual and continuous, with marked differences of rate. He concludes that research productivity has never been significantly correlated with physiological states. Alexander (4) found that scientists as a group have a mean longevity of 2.99 years more than artists, and attributed this difference to the higher living standards enjoyed by the former.

The median age at which scientists do their best work is forty-three, according to Adams (1). The range extends from mathematicians with a prime age of thirty-seven to anthropologists with a prime age of forty-seven.

Lehman (123) compared man's creative years in the past and the present, studying a variety of creative occupations. He found that as a group the more recently born contributors have been somewhat younger at the time of making their most important contributions. The age of maximum productivity for the scientists and artists is established as between thirty and thirty-five. The picture of the creative scientist is that of an individual showing his abilities at a relatively early age, and doing his most creative work in his late twenties or in his thirties. His peak varies with his field, but he continues to produce for a long period thereafter.

Starred and non-starred scientists in *American Men of Science* were compared by Poffenberger (156). The age range for the conferring of degrees was almost exactly the same for both groups, with the median age younger for the starred group. Mathematicians earned the doctorate earlier than the other scientific groups. The median age at which names appeared in the directory was about two years less for starred than for non-starred scientists.

Conclusion. Scientists continue to be productive until a later age than men in general, and live longer. They tend to start producing early, and reach their peak productivity in their thirties or early forties.

Age of parent

The age of the father when his gifted son was born tended, Raskin (157) found, to exceed the usual age of paternity. For fathers of scientists the average age was thirty-eight. In Visher's study (211) the age of 25 per cent of the fathers when the scientist was born was between twenty-five and twenty-nine, and of 33.3 per cent, between thirty and thirty-five. The mother was most frequently between twenty-four and thirty-three years of age.

Sex differences

Sex as a variable in scientific careers has been studied by a few investigators. According to Edgerton and Britt (53) boys as a group were more frequently selected as contestants and did significantly better than girls on the Science Talent Search test. The authors suggest that these differences are due to environmental and cultural factors rather than to biological differences. In his summary of the studies on eminent persons, Smith (180) found a superiority of men over women. Strong (186) and Yum (226) showed that sex differences existed in the frequency of scientific preferences, men being more likely to be interested in science. Zim (228) discovered that the number of adolescent boys active in science was about five times the number of adolescent girls.

Physique and body build as factors

Begelman (12) attempted to relate body build to occupational choice. He found that items such as physical performance, adipose tissue, and muscle tissue showed no relationship to vocational choice.

The physical differences between ranking and nonranking boys in the Science Talent Search were studied by Edgerton, Britt, and Norman (55). Their study showed that ranking subjects were definitely superior in physical condition, with slight but nonsignificant superiority in height and weight. Smith (180) concluded that eminent men appear to possess a superior degree of height and weight and of height-weight ratio, of head size, cranial capacity, and brain weight.

KEY PERSONS AND EXPERIENCES

The importance of the human qualities of the individual teacher was stressed by Knapp and Goodrich (109) as basically influencing the student in the pursuit of science. The following persons were listed by Visher (211, 212) as influenceing the decision to do scientific work: high school teacher in one-sixth of the cases, college teacher in 42 per cent, father in 15 per cent, and other relatives in 10 per cent. He concluded that encouragement from one or more deeply respected people is of greatest importance.

Academic opportunities and qualified teachers are important influences on the choice of a scientific career, as seen by Brandwein (28). The influences of parents and relatives are also mentioned. According to Roe's study (168), eminent scientists frequently were led to embark on a scientific career by a school or college project. However, occasionally some other activity provided the stimulus and the opportunity to do research. Having discovered the pleasures of this work, particularly the possibility of finding answers to questions by experimentation, the student continued in that direction.

Such factors as parental encouragement, parental attitudes toward self-development, friends and associates interested in science, books, and a science teacher are mentioned by MacCurdy (127) as contributing toward choice of a scientific career.

Parental emphasis on independent growth as tending to develop the achievement motive was stressed by McClelland (142).

The completion of homework assignments was found by Perkins (154) to have no significant relationship to achievement in general science. He concluded that the learning of subject matter occurs in the classroom and appears to be more closely related to reading ability than to completing homework.

Conclusion. Reviewing work in this area, Cole (41) concurred as to the importance of family background, exposure to scientific study, and the encouragement of a teacher as basic factors influencing the student to choose a scientific career. These facts being established, we need to know how they operate.

MISCELLANEOUS FACTORS

In this section are included variables which did not fit logically into previous sections. These are the earnings of scientists, their occupational mobility, and the factors other than those discussed earlier which are related to scientific achievement.

The highest median salaries of scientists, $6670 in a 1948 survey, were found by Clague (39) to be earned between the ages of fifty-five and sixty. The salaries declined only slightly through ages sixty-five to sixty-nine.

The occupational mobility of scientific and technical personnel was studied by Wood (223), who concluded that there is significant movement from one specialty to another even among Ph. D.'s. In a study of starred and non-starred scientists in *American Men of Science,* Poffenberger (156) noted that differences in occupational shifting were negligible, although the starred group did slightly more shifting.

According to Van Zelst and Kerr (207), individuals with the greatest scientific and technical productivity have more honorary and professional memberships, read more journals, have less belief in equalitarian practices in research, greater belief in the voluntary determination of deadlines, and more selflessness in motivation than less productive workers. The more productive individuals held more degrees, age held constant.

SYNTHESIS

GENERAL OBSERVATIONS

The portrait of the natural scientist which emerges from the general (nonresearch) literature is that of a paragon. In terms of the general characteristics stressed by observers and biographers he is ingenious, curious, industrious, and shows a good deal of initiative. He is devoted to his work, manifests challenging attitudes, has strong inner-directedness, is enthusiastic and exceptionally honest. He possesses originality, analytic ability, and powers of imagination and observation. He is, furthermore, trustworthy, determined, optimistic, self-confident, courageous, tolerant, and generous. He possesses a strong desire to excel. It is noteworthy that these are generally desirable traits.

Research

Intelligence. Investigations which are more scientific in their methods show that the scientist is of superior intelligence, is capable of rigorous and abstract thinking, and has a capacity for superior achievement. He and his kind are found within a surprisingly wide range of intellectual ability. He is, with a few dissents, a superior reader possessed of good verbal reasoning ability, with an extensive vocabulary and facility of expression. He is verbally fluent, flexible, and original. He and his peers manifest a wide range of superior ability.

There are some suggestions of different intelligence patterns for different kinds of natural scientists. Their quantitative skills are superior. They possess high mathematical talent and the ability to formulate mathematically and to think quantitatively. In this ability area, too, there is a fairly wide range.

Scholarship. Superior scholarship is typical of the natural scientist in both high school and college. He commonly comes from the top 10 per cent of his freshman class, and has earned advanced degrees. He is typically an honors graduate, attaining greater prominence with higher academic honors. He has studied, typically, at a college or university where the student body and mores show a lack of preoccupation with social life and intercollegiate athletics.

Special Aptitudes. The natural scientist is characterized by superior spatial visualization, mechanical comprehension, manual dexterity, and manipulative ability. He possesses such complex mixtures of aptitudes, personality traits, and experience as science judgment, originality, adaptive and spontaneous flexibility, ability to redefine and to formulate problems, the abilities to plan and design an investigation, to conduct the investigation, and to prepare appropriate reports.

Personality. In terms of personality traits and patterns, the scientist appears less of a paragon. He shows self-confidence, an absence of marked feelings of inferiority, is introverted, and displays asocial tendencies. He has strong leadership drives, is not conscious of the nature of his motivating forces, is characterized by late psychosexual development, and is somewhat poorly adjusted socially.

He shows childhood feelings of isolation, feels independent of his parents with little discomfort over this, shows controlled intellectuality and intellectualized emotional energy. He is goal-oriented and persevering, self-disciplined, and tolerant. He has been found to be self-sufficient, generally emotionally stable but unconventional.

Natural science students have been found freer of neurotic trends than social scientists and arts and humanities majors. The scientific researcher is characterized by lack of paranoid trends and of free-floating anxiety. Nevertheless, the research literature gives considerable support to the stereotype of the scientist as a lonely, socially inadequate and somewhat withdrawn person who is superficially effective in interpersonal relations, curious, self-disciplined, unemotional but tolerant of others, persevering in and intensely devoted to his work.

The future natural scientist's interest in science and mathematics is displayed relatively early in life and is relatively constant. This early interest is in scientific facts or phenomena rather than in science in the broad sense. It takes the form of scientific hobbies such as high fidelity, electronics, crafts, photography, mechanical pursuits, chemistry, electricity, radio, motors, and first aid. Some researchers characterize this science interest as concentrated in one or two fields. Others speak of a broader interest pattern overflowing into activities such as music, art, sports, and general reading, as well as scientific activities. The age of crystallization of scientific interest appears to extend from about ten to fourteen. The age at which science interest results in the choice of a scientific career appears to range from about fourteen to twenty.

The natural scientist tends to come from an upward-mobile middle-class family background, characterized by favored parental, economic, educational, and occupational status. His father in many cases is a college graduate and a member of a profession. The natural scientist is typically either the only boy or the eldest child, whose father is native-born. The typical American scientist tends to come from English, Scottish, Scotch-Irish, or German stock, has either a rural or an urban origin, and comes from a Northern or Western region. The general picture is of an intellectually stimulating and well-endowed environment.

Religious groups which encourage inquiry tend to produce scientists, but the typical scientist does not appear to be a regular churchgoer. Moreover, a recent study suggests that differences in religious background are becoming less significant. This study showed no significant religious differences among natural science, social science, and humanities students. Since students are *future* members of occupations, this finding suggests that currently changing socioeconomic and psychological factors associated with religion may actually be the determinants rather than the religious beliefs or values.

The natural scientist does his most productive work at a fairly early age, between thirty and thirty-five, the peak varying with the field. But he keeps on being productive, and for a longer period than the average man. Productivity is associated with continuing professional activity, a preference for self-determination of deadlines, and selflessness of motivation.

The general superiority of men over women in scientific achievement is revealed by a few studies. Again the culture is probably a major determinant.

The superior physical condition of scientists over the population in general has been confirmed by several studies, but attempts to correlate body build with occupational choice have tended to yield no significant results.

Factors which directly influence the natural scientist to choose this career include family and key figures, such as the father, other relatives, or high school or college teachers; academic opportunities; and experiences of an educational nature, such as a laboratory project or reading certain influential books. The importance of key figures, exposure to scientific study and experimentation, and encouragement seems well established.

Chapter III

THE MATHEMATICIAN

THE few available research studies of mathematicians are limited in scope. The articles located are reviewed in terms of intellectual, personality, and cultural factors.

INTELLECTUAL FACTORS

Ways of identifying students with scientific and mathematical potential were listed by Fehr (64). Traits believed to be significant are extraordinary memory, abstract thinking of a high level, application of knowledge, intellectual curiosity, superior vocabulary, facility of expression, intuition, creativity, and a sound knowledge of advanced areas. Révész (159) stated that talent for mathematics is a special talent, clearly distinguishable from and independent of other scientific skills. He suggests that there are hereditary aspects to this talent which develop before the age of sixteen. The author cites Poincaré's classification of scientists into two categories: those with analytic minds, whose inventions are defined by logical mathematics, and those with intuitive minds, who are called geometrists. It will be shown below that some of these opinions are not supported by the meager evidence available. The relationship between scores on the Scholastic Aptitude Test and mathematics grades was examined by Dickter (49), French (72), and Riegel (161). The verbal section of the Scholastic Aptitude Test correlated between .15 and .29, with a median of .19, with grades in trigonometry, college algebra, analytic geometry, and calculus. Correlations between scores on the mathematics section and mathematics grades ranged from .37 to .59, with a median of .46, a very stable relationship.

French (71, 73) attempted to determine the relationship between what he judged to be the purest measures of the factors in mathematics achievement and mathematics grades in a college-level military academy. The highest correlations were found to be between his measure of verbal comprehension, deduction, space, number, visualization, and induction factors, with a range between .27 and .53.

In a study of certain factor-analyzed abilities and success in college mathematics, Hills (97) selected sixteen factors for detailed consideration. The nine factors ultimately selected were: eduction of patterns, originality, numerical facility, verbal comprehension, adaptive flexibility, general reasoning, logical evaluation, spatial visualization, and spatial orientation. These factors were measured by tests, and the scores were correlated with mathematics test scores and ratings by professors. Of the 199 correlations, 18 were significant at the .05 level and 11 at the .01 level. Eduction of patterns yielded one significant correlation. The measure of originality had no significant correlations, while numerical facility had four—one of which was .68. The general reasoning test yielded only one significant correlation, whereas logical evaluation displayed four, one of them reaching .72. Spatial visualization had three significant correlations. The largest number of significant correlations, 10, was obtained by the spatial orientation test. Using such accepted criteria of success in mathematics as grades and ratings, Hills came to the conclusion that there is no particular ability or set of abilities which is universally associated with success in mathematics, and therefore mathematics aptitude is not a fixed entity.

Riegel (161) found correlations ranging from .46 to .65 between scores on the mathematics section of the Scholastic Aptitude Test and grades in engineering mathematics.

The prediction of success in advanced college mathematics was attempted by the Kinzers (107). The authors reported that the Ohio State Psychological Examination correlated between —.16 and .43 with college mathematics courses. Better students in the early courses tended to go on to more advanced work. The cumulative point-hour ratio correlated to .63 with grades in advanced calculus. Significantly higher grades in mathematics were achieved by students who went to college immediately after graduation from high school.

The correlation between an entrance examination battery and grades achieved in mathematics was studied by Bromley and Carter (29). The battery consisted of such tests as a mathematics comprehension test, silent reading test, and the ACE Psychological Examination. Correlations were positive but low, ranging from .11 for silent reading to .35 for mathematics comprehension. Rank in high school predicted mathematics grades somewhat better, with a correlation of .40. The authors concluded that achievement in this area is substantially influenced by factors other than those investigated in their study.

The development of tools for counselors in the field of mathematics was attempted by Seigle (174), who found that his entrance mathematics test had predictive value for success in college mathematics. This test predicted more efficiently for college algebra than for trigonometry, analytic geometry, and calculus. High school average was the second best predictor of success in college mathematics before any college mathematics was taken. After some work in college mathematics was completed, the best predictor was the grade attained in the previous course. The amount of high school mathematics taken seemed to have little relationship to courses other than the first college course.

The value of various predictive measures for forecasting grades in mathematics courses was investigated by Frederiksen (70). He found that a mathematics aptitude test, a mathematics achievement test, and converted school grades were fairly good predictors, with correlations in the .50's. Measures of verbal ability and level of comprehension had low positive correlations, in the .20's, with mathematics grades. The amount of time elapsing since high-school graduation appeared to be unrelated to success in college mathematics for the investigators' veteran group.

Studies such as those summarized above give some clues as to factors making for success in the study of mathematics, despite Bromley and Carter's (29) somewhat pessimistic conclusion. But they contribute little to the understanding of the characteristics of mathematicians, except in so far as success in college mathematics (in which many succeed without becoming mathematicians) is a prerequisite to becoming a mathematician. A few studies focus on the occupation or on majors in the field. Thus Harmon (88) found that mathematics majors have superior quantitative and verbal skills and do superior work in the science areas.

The relationship between selected test behavior and creativity in mathematicians and chemists was studied by Walker (213). A small group of creative mathematicians and chemists was compared with a small group not considered so creative. Factors such as originality, flexibility, fluency, sensitivity, and concentration were assessed by means of projective and objective test performances. No differences between mathematicians and chemists were established, nor did significant differences emerge, generally, between the creative and noncreative groups.

In a study of eminent scientists, Poffenberger (156) found that mathematicians get their Ph. D.'s earlier than persons in the other scientific occupations.

Conclusion. Homo mathematicus thus appears to have gone virtually unnoticed and unstudied by students of men and of occupations. According to the relatively few studies, success in mathematics has been found to require superior mental ability, including verbal as well as quantitative aptitude. Varying combinations of special aptitudes rather than any one particular combination make for good grades in mathematics, and early achievement tends to predict later achievement in mathematical studies. Little is known, however, about the *differential* intellectual abilities of mathematicians.

PERSONALITY TRAITS AND CULTURAL FACTORS

The personality characteristics of mathematicians are almost entirely unexplored by scientific methods.

Fehr's list of the presumably significant personality traits of scientists and mathematicians (64) includes the possession of a hard-ridden hobby and persistent goal-directed behavior. Burington and May (34) also developed a list of presumably essential and generally desirable traits. Again, however, data are sparse.

The backgrounds of high school seniors who elected fourth-year mathematics and those who did not were compared by Schmitt (173). A questionnaire was used to gather the data in five schools located in towns and cities of various sizes in New York and Massachusetts. A number of socioeconomic and cultural factors which were present in greater strength in the mathematics group than in the nonmathematics group were identified. These are: religion (Jewish); employment of father in mathematics, science, or another profession or some type of self-employment; father attended or went beyond undergraduate college; father majored in mathematics or engineering; and mother attended college and majored in education or science. In addition, a foreign language, frequently Jewish, was spoken at home; there were no brothers in the family, and the mathematics student engaged in either no hobbies or certain specific hobbies, such as photography, science, and gardening. He was superior scholastically, had no work experience, was active in school extracurricular activities, read a good deal, did not go to parties or dances. He spent more time on mathematics than on any other subject. Girls majoring in mathematics were seen to possess the same distinguishing background factors, but to a greater extent.

Industriousness and its relationship to achievement in college mathematics have been studied by Krathwohl (114, 115, 117). He found that indolent and industrious students in high school mathematics tend to show this same trait in college mathematics. There appears to be a limit, however, to the amount of mathematical knowledge which students of low mathematical ability can acquire, no matter how industrious they are. An index of industriousness was established and correlated between .27 and .51 with grades in college algebra (in a later study, from —.08 to .41), with significantly better correlations for the brighter students. When groups are classified according to ability, work habits contribute more toward achievement than mathematics aptitude. There was a tendency for the industrious to have higher correlations between ability and achievement than indolent students.

Men's achievement in mathematics was superior to that of women in a study by Bramwell (23), a fact generally revealed by analyses of school or college grades. Reference has been made previously to the findings of Mallinson and Van Dragt (129) that there is some stability in mathematics interest between grades nine and twelve, but that this interest is not a good predictor of mathematical talent. Strong's work on inventoried interests (186) has also shown considerable stability, but low predictive value for interest measures when grades are the criterion. Apparently ability and motivation determine achievement, while interest is a predictor of choice. Strong has thus shown (186a) that interest is related to ultimate field of work.

The personality organization of a selected group of highly creative mathematicians and chemists was investigated by Clifford (40). A battery of projective and psychometric devices was used to examine six selected mathematicians and twelve selected chemists. Superior perceptual and associative organizational ability characterized this creative group. Conceptual flexibility and the ability to handle environmental problems without serious interruption from anxiety or affect also marked the group. These creative scientists were found to be attentive to the details of an environmental problem and capable of dealing with the problem in daring and unusual ways. The data suggested that the subjects reacted to other people in an objective, cold, and competitive fashion. Clifford concluded that creativity is a positive method of maintaining personality integration in that it affords the creative person an opportunity to utilize his full capacity for personal development and gratification. He believes, like most other students in this field, that creativity in mathematics or chemistry is not a general capacity but a complex of capacities which varies with the characteristics of the person, the nature of the interaction between the person and his colleagues, and the larger cultural matrix in which they work.

In a biographical study of mathematicians, Bell (13) found them normal in ordinary social contact, with a percentage of eccentricity no higher than that in commerce or the other professions. They were keenly interested in many things in addition to mathematics. He also found them courageous, vigorous, alert, and tremendously accomplished, with a strong interest in studying mathematics. Politically they ranged from left to right, and religiously from narrowest orthodoxy to absolute skepticism. The great majority of them were happily married and reared children intelligently. The mathematicians were normally concerned with personal appearance and lived more varied and richer lives than most people. The claim that expertness in mathematics makes for quarrelsomeness and bad temper is not supported by Bell's findings.

SYNTHESIS

The good student of mathematics, the mathematics major, and the mathematician emerge from the scant literature as persons of superior intelligence and of superior achievement in school and college. Measures of intellectual factors yield moderate correlations with mathematics achievement, and varying combinations of factors make for good grades. The special aptitudes of mathematicians have not been studied.

The mathematician comes from a superior socioeconomic and cultural background in which religious factors, or perhaps more accurately the psychological or cultural characteristics of a particular religious group, have permitted or encouraged an inquiring attitude, and in which a solitary position in the family and casual or cold interpersonal relationships have been important. Such complex and high-level intellectual traits as originality, flexibility, fluency, sensitivity, and concentration, often listed as important on a priori grounds, do not appear to be specific determinants of success in mathematics in the few published empirical studies.

The personality structure of the mathematician seems to be that of an objective, cold, and competitive individual in his interpersonal relations, with relative freedom from anxiety and little affect. At the same time, the mathematician is normal in his social contacts, he is not an eccentric. But much remains to be learned about workers in this field.

Chapter IV

THE ENGINEER

THE field of engineering will be explored in much the same fashion as were the fields of natural science and mathematics. Initially the intellectual factors will be discussed, then the special aptitudes, personality factors, and interests, and family, socioeconomic, and cultural factors.

INTELLECTUAL FACTORS

INTELLIGENCE (GENERAL)

In an early study, Wilson and Hodges (218) compared the results of the Otis Advanced Intelligence Test with engineering grades and established a maximum correlation of .42 between these variables. Mercer's (145) analysis of the factors of scientific aptitude which appeared to indicate success in engineering curricula showed a factor of general mental alertness.

In a study of the prediction of success in engineering and physical science courses, Coopridder and Laslett (42) found that engineering grades could have been predicted as well by the ACE Psychological Examination total score ($r = .51$) as by the Engineering and Physical Science Aptitude Test and the Stanford Scientific Aptitude Test.

The ACE proved to be the best device for classifying engineering students by ability group in Holcomb and Laslett's (98) study of engineering aptitude. According to Johnson (102), the ACE was a good predictor of graduation from engineering school. This test was also found by Malloy, Wysocki and Graham (130) to be a good predictor of survival in first-year engineering. McClanahan and Morgan (141) reported that the ACE correlated .65 with the grade-point average in engineering college courses. Eels and Reetz (57) found that students selecting engineering as an occupation scored significantly higher on the ACE than the average junior college student in California. Pierson's (155) study of engineering school dropouts showed that the majority of students enrolled from 1928 to 1937 possessed the ability to succeed academically. This suggests the importance of other factors to supplement existing selective processes which stress intelligence.

According to Berdie and Sutter (16), the General Educational Development Test was almost as good a predictor of success in academic engineering as was rank in the student's high school graduating class.

Studies of the role of general intelligence in the occupation, as contrasted with training, have been less numerous. Harrison, Hunt, and Jackson (91) studied employed mechanical engineers and found superior general intelligence as measured by the Wonderlic and Shipley Tests. Similar results were obtained by Treumann and Sullivan (204), Mann (135), and others with the ACE Psychological Examination. The field of engineering is divided into specialties such as design, sales, manufacturing, research and development, and erection, by the Allis-Chalmers report (5). This report assessed the needs of each field in terms of intelligence as measured by the California Test of Mental Maturity. The intellectual requirements for the various fields range from medium for erection engineers to very high for research and development. Other fields appear to require high intelligence.

Conclusion. Superior general intelligence characterizes the engineering student and engineer in most studies reviewed. It contributes to success in training. The possibility of a relationship between general intelligence and degree of success in engineering, as contrasted with ability to enter or remain in the occupation, has apparently not been studied.

Verbal intelligence

Bernreuter and Goodman (17) compared engineering freshmen with high school seniors. They found that engineers did significantly better in deductive reasoning and possibly surpassed high school students in verbal ability. Engineers appeared to be somewhat inferior, however, in inductive reasoning. Dunnette (51) concluded that his verbal analogy test involving engineering knowledge had proved itself useful for the evaluation of engineering students. Vaughn (210) incorporated in his engineering aptitude test a section devoted to the comprehension and interpretation of scientific material, and Sackett (171) used tests of general verbal and technical verbal ability which likewise had some validity for success in engineering school.

In an analysis of success in an engineering curriculum, Mercer (145) discovered a factor dependent on verbal academic ability. Goodman (79) reported that verbal and reasoning factors become more significant as engineers advance in training, and differentiate significantly those who drop out of engineering school from those who graduate.

It is of some importance that, studying adults engaged in the occupation rather than students, Harrison, Hunt, and Jackson (91) found that mechanical engineers have superior verbal problem-solving ability. Engineers did as well on verbal tests as on nonverbal. Confirmation is provided by a study of successful engineers in which Moore and Levy (146) reported that the verbal aptitudes of engineers were about as good as those of the business man. Similarly, the Allis-Chalmers study (5) showed that erection and manufacturing engineers needed average verbal comprehension, sales engineers high ability of this type, and design and research-development engineers a very high degree of verbal comprehension as compared to that needed by the general population.

Conclusion. We may conclude that the significance of verbal ability in engineering is not just a function of need to perform the verbal tasks of school or college, but also a requirement of the daily work of most adult engineers.

Quantitative intelligence

In a study of the prediction of academic engineering achievement, Treumann and Sullivan (204) found that the quantitative score of the ACE Psychological Examination had little predictive significance. The ACE total score and the Engineering and Physical Science Aptitude Test (which stresses quantitative aptitudes and skills) appeared to be better indicators. That the quantitative part of the ACE is not superior to the ACE total score for predicting academic success in engineering was confirmed by Coopridder and Laslett (42).

In an evaluation of a battery assembled to predict the success of engineering students, Berdie and Sutter (16) discovered that a mathematics test contributed sufficiently to prediction to warrant its inclusion in the battery. Feder and Adler (62) also found that a mathematics aptitude test yielded a satisfactory predictive correlation with scholastic achievement in engineering school. On the other hand, a mathematics test was reported by Malloy, Wysocki and Graham (130) to contribute least to the prediction of attrition or survival in a school of engineering. Such other variables as ACE scores, a spatial relations test score, and a reading test score proved to be better predictors of survival.

A study of thirty successful engineers, as distinguished from the students in the above studies, used a personal data sheet, educational records, and a projective personality test. According to this study by Moore and Levy (146), engineers possessed superior or very superior intelligence in dealing with structural rather than verbal problems. They were practical thinkers with a tendency to limit their attention to immediate problems.

In a study of the selection of engineers, Mandell (132) found that results of a mathematics formulation test were related to ratings of high job performance. Superior performance on the Otis Arithmetic Reasoning Test characterized the mechanical engineers studied by Harrison, Hunt, and Jackson (91).

Conclusion. It is noteworthy that quantitative intelligence appears to be more consistently correlated with job than with academic success in engineering. Most studies do not yield the expected high correlations between quantitative ability and success in engineering school, although the engineering student is characterized by superior quantitative ability and this type of aptitude is related to success in the occupation.

SCHOOL ACHIEVEMENT

Marks in grade twelve proved to be almost as good an indicator of academic success in engineering, according to Laycock and Hutcheon (121), as a battery of spatial, mechanical, and intelligence tests and an interest inventory. In a study by Jones (104) the most efficient predictor of academic success in engineering was a combination of secondary school grades, a mathematics test, and a physics or chemistry test, with a correlation of about .65. Johnson (101) too found that high school rank, a mathematics orientation test, and a physical science test were effective predictors of graduation from engineering school, more so than the Purdue English Placement Test. The high school records of engineering students correlated about .65 with mathematics tests. The number of units of high school mathematics proved to be suggestive of success in engineering college.

The investigation of the relationship of secondary school preparation to success in college engineering by Feder and Adler (62) established that the more extensive the high school mathematics training the higher the achievement in engineering college.

It is noteworthy, however, that Pierson (155) found that grades earned in high school English were as closely related to engineering achievement as were high school mathematics grades. Supporting this evidence of the importance of verbal proficiency, McClanahan and Morgan (141) reported a correlation of .495 between a reading test and grade-point average of engineering students.

A comparison of students remaining in the engineering curriculum and those transferring from engineering to other curricula was made by Sadler (172). This comparison showed that engineers were superior to non-engineers in linguistic achievement and in English effectiveness and reasoning ability. Non-engineers showed a slight, nonsignificant superiority in word fluency. Stuit (188) also found that most studies of success in engineering listed proficiency in English as an essential qualification.

Moore (147), however, reported that in his institution mathematical ability continued to be the best single predictor of academic success in engineering. Students transferring to other departments had done significantly less well in high school mathematics than those remaining in the engineering curriculum. A slight relationship between the amounts of high school work in science, mathematics, and manual training and success in college engineering was similarly found by Boardman and Finch (21), and a correlation of .50 was reported by Long and Perry (126) between scores on a general mathematics ability test and four-year average engineering grades.

In a study of the Engineering and Physical Science Aptitude Test as a predictor of academic success in engineering, Griffin and Borow (84) found that most of the subtests had greatest predictive efficiency for subjects to which they seem logically related; for example, the mathematics subtest with mathematics grades and the physical science comprehension subtest with physics grades.

In a study of engineering freshmen, Cryer (44) concluded that students who cannot or will not pass mathematics and physics in their first semester might be better off in another department. Higgins (96) reported a correlation of .84 between the average grade in freshmen mathematics and the average total grade for the four-year engineering course.

It seems clear that mathematical proficiency, as well as proficiency in English, is related to success in engineering school. Both are tool subjects, essential to the work of the engineering student.

Tests in physics, chemistry, and physical sciences in general have been found, in studies such as those of Johnson (101), Jones (104), McClanahan and Morgan (141), and Moore (147), to be fairly good predictors of academic engineering ability, with correlations generally in the .50's and .60's.

The best single predictor of the over-all engineering college average is high school rank, according to Berdie and Sutter (16). Johnson (102) found that 74 per cent of the upper third of high school graduates complete their engineering course, in contrast with only 45 per cent of the middle third, and only 19 per cent of the lower third. The correlation between high school average and four-year average grades in engineering was .40, as reported by Long and Perry (126). Bartlett (11) also reported that high school rank was the most reliable index of success in the engineering curriculum. In one contradictory study, however, McClanahan and Morgan (141) found that high school rank was the poorest predictor of academic achievement in engineers, among such variables as intelligence, scholastic aptitude tests, reading, chemistry, and English tests.

The need for further critical evaluation of college grades as a criterion is stressed by Moore (147). It is obvious that variations in results obtained may be due to variations in grades and grading. Despite this, Pierson (155) showed that graduates of engineering curricula proved to have been high school students of superior achievement, that the grade-point average for the typical engineer fell from high school to the first quarter in college, and that first-quarter and first-year point ratios were more closely related to engineering scholarship than any particular subject grade. He concluded that the grade-point average in engineering school is a valid basis for predicting success in engineering practice.

The academic records of employed engineers appear to have been studied only by Mandell (132), who found that those who fell in the lower half of the engineering graduating class tended to be inferior in job performance.

Conclusion. Studies of the use of tests for the selection of professional college students were summarized by Stuit (188), who concluded, as we do here, that superior aptitude for college work as judged by high school achievement is an essential qualification for engineering studies. The conclusion is as valid now as it was in 1949.

SPECIAL ABILITIES AND APTITUDES

SPATIAL VISUALIZATION

The development of a pre-engineering battery (including a spatial visualization test) to be used in the discovery of engineering talent was described by Sackett (171). Mercer (145) reported that one of the factors in success in the engineering curriculum was the mental manipulation of spatial relations. Superiority in the space factor characterized successful engineering students studied by Goodman (79).

Bernreuter and Goodman (17) reported, however, that spatial ability is only slightly correlated with first-semester grades of engineering students. The fact that a group is superior to another in some characteristic obviously does not mean that a relationship between that trait and success will be found in the superior group. Spatial tests such as the Minnesota Paper Form Board and the Minnesota Spatial Relations were found by Brush (32) to correlate .42 and .06 respectively with first-year grades in engineering courses. (The paper form board contains a heavier loading of abstract reasoning or intelligence than does the actual form board.) According to Malloy, Wysocki and Graham (130), the Minnesota Paper Form Board was an effective predictor of attrition or survival in first-year engineering.

In his study of engineers employed by the government, Mandell (132) found a correlation of .32 between scores on a spatial visualization test and job performance. The generally superior achievement of mechanical engineers on a space relations test was noted by Harrison, Hunt, and Jackson (91). The Allis-Chalmers (5) study reported that a medium degree of visual logic was necessary for sales engineering, and that a high degree of this aptitude was basic to other areas of engineering such as design, manufacturing, research and development, and erection.

Conclusion. In his summary of studies in the prediction of success in engineering, Stuit (188) concluded that average or better spatial visualization is an essential for success in this field. The conclusion still seems valid, even though spatial visualization may not be correlated with degree of success in successful student engineer groups. Success in the work of an engineer does seem to be related to spatial aptitude.

Mechanical ability

Sackett (171) and Vaughn (210) felt that the ability to understand mechanical principles was important to engineers, and included such a test in their engineering aptitude battery. Mechanical aptitude as measured by some of the early tests of this factor was found by Brush (32) to bear a significant relationship to success in engineering courses. However, this relationship was not considered close enough to make this single test particularly useful in prediction. In another relatively early study assessing the prognostic value of several tests for achievement in engineering school, Holcomb and Laslett (98) reported that some mechanical tests had no predictive value, whereas others gave a "fair clue" to success. The correlations were too low for much reliance on these latter tests alone.

Using a more recently developed and more appropriate type of mechanical aptitude test, Halliday, Fletcher, and Cohen (87) studied the relationship between the Owens-Bennett Mechanical

Comprehension Test and first-quarter grade averages in engineering. They found a correlation of .42. However, the Ohio State Psychological Examination was a better predictor than the above test for engineering grades. The intercorrelation of the two tests is such that the Owens-Bennett test does contribute to distinguishing those who will complete the engineering courses from those who will not. The author of this test, Owens (151), also reported on it as a potential selector of engineers. He found that engineering seniors obtained higher mean scores than architectural engineering sophomores, engineering freshmen, or agricultural engineering freshmen. He further reported that this test correlated between .28 and .49 with engineering course grades. The biserial correlation with a pass–fail criterion in the engineering course was .59. The test appears to be able to distinguish the more able students from the less able.

A mechanical comprehension test was much easier for mechanical engineers than was a spatial relations test, according to Harrison, Hunt, and Jackson (91). The mechanical comprehension of employed engineers was assessed by the study at Allis-Chalmers (5). Sales engineering appeared to require an average amount of mechanical ability; a high degree was needed by erection, manufacturing and design engineering; and a very high degree was necessary for research-development engineering.

Conclusion. Average or better mechanical comprehension was included by Stuit (188) among the traits essential for success in the study of engineering, as a result of his analysis of the research. The evidence seems firmer today, as a result of the development of more appropriate tests. The conclusion seems applicable also to employment in engineering, although there is little relevant evidence.

Other complex abilities

In analyzing scientific aptitude factors related to success in engineering curricula, Mercer (145) suggested the importance of analytic reasoning. Superiority in reasoning ability too seemed to characterize the student engineers studied by Goodman (79). In an aptitude test of engineers, Koerper (112) tested for such skills as ability to deal with critical details, scientific and research ability, and the ability to organize technical work. In another article (113) he listed the following abilities as essential to the young engineer: understanding the practical application of his academic work, developing an organizational sense, understanding the economic significance of his decisions, developing a sense of professional balance, and developing personal insight.

Mandell (132) tested for ability to read tables and the ability to evaluate hypotheses. The engineer is described by Moore (147) as a practical thinker who is ingenious rather than creative.

PERSONALITY FACTORS AND CHARACTERISTICS

Personality as a factor related to the choice of and success in an engineering career has been investigated less extensively than intellectual factors.

In an early study in which professional teachers rated a list of traits which now seem inappropriate for such study, Dashiell (46) found little differentiation among the professions of law, medicine, commerce, teaching, and engineering. Such traits as truthfulness, good appearance, patience, originality, open-mindedness, good memory, leadership, industry, and honesty were commonly listed for all professions. Dashiell concluded that aptitude for acquiring specific knowledge and skills appears to be more important than the personality traits investigated. He did suggest, however, that opportunities for training and motivation of the individual may be important for achievement in most professional areas.

In an assessment of the psychological factors conducive to success in chemical engineering, Speer (184) listed effectiveness in dealing with people and suggested that the success formula is teamwork, tact, teaching, interest, and initiative. MacCutcheon (128) listed integrity, dependability, and determination as important traits of the engineer. Bangs (8) gave the personality requirements as character, initiative, willingness to work, and tact in dealing with others.

Mann (135) felt that the scholastic aptitude factor has been overplayed, and devised a personograph to reflect the whole individual: his personality, mentality, scholarship, and professional and scientific interests. Berdie and Sutter (16) also suggested that more accurate predictions of the success of engineering students could be effected by using interest and personality tests in addition to the traditional tests commonly used.

In a review of a decade of attempts to predict scholastic achievement, Moore (147) concluded that the measurement of aspects of mental ability is not enough. The exploration of such other factors as industriousness, initiative, imagination, persistence, socioeconomic status, health, and moral and volitional habits was deemed necessary. In keeping with this, Pierson (155) found that academic adjustment problems characterized the first-year performance of engineering students.

A decided tendency for the ascendant student, as measured by the Allport Scale, to make low grades in engineering, was noted by Holcomb and Laslett (98). Goodman (79), using the Bernreuter, reported that engineering students are more stable and self-sufficient than liberal arts students. Koerper (112) described an engineering test battery in which he included tests to measure such psychological traits as self-reliance, drive, social intelligence and tact, leadership, dependability, professional aspiration, and development.

An investigation of students preparing for the five selected professions of mechanical engineering, education, law, medicine, and journalism was made by Blum (20), who used a questionnaire, the Minnesota Multiphasic Personality Inventory, and the Strong Vocational Interest Blank. He found that depression and social introversion correlated significantly with inventoried interests like those of engineers, mathematicians, physicists, and chemists. Mechanical engineering students scored highest of all groups on the hysteria scale, lowest on the schizophrenia scale, and highest on social introversion, suggesting traits of immaturity, good contact with reality, and a preference for things and ideas rather than association with people.

Judges were able to predict survival and attrition of engineering students on the basis of a combined profile of Guilford temperament scores, Kuder interest scores, and first-quarter college grade point average in a study reported by Truesdell (205).

The self-concepts revealed by responses to personality adjustment questionaires differentiated high- and low-achieving engineering students studied by Crooks (43). With the refinement and combination of his instruments into a single composite scale, he established a correlation of .55 between his scale and first-term grades.

Over- and under-achievers in the engineering curriculum were studied by Burgess (33), using the Rorschach, Minnesota Multiphasic Personality Inventory, Thematic Apperception Test, Rosenzweig Picture Frustration, and other tests. She found that the Rorschach variables did not discriminate significantly between the two groups, although a few signs were significant on a few cards. On the TAT, over-achievers scored significantly higher on achievement, aggressive, status, and self-improvement needs. Under-achievers scored significantly higher on dependent needs and needs to be free of restraint. No significant differences were established using the Rosenzweig, MMPI, or Bernreuter tests. All seven variables of the Borow College Inventory of Academic Adjustment favored the over-achievers, with significant differences in the areas of personal efficiency, planning, and use of time. She concluded that as a group over-achievers show the following differentiating personality factors: less labile, more constricted and inhibited, more intellectually adaptive, more cautious and realistic in approach to problems, and greater need for achievement and self-improvement.

Personality studies of graduate engineers have been more common than have studies of their aptitudes, perhaps because college records are less revealing of these traits.

Mechanical engineers studied by Harrison, Hunt, and Jackson (92) were found to be social conformists, showing a close rapport with commonly accepted beliefs and practices. Interviews, questionnaires, and projective techniques used by Harrison, Tomblen, and Jackson (93) showed that mechanical engineers possess a wide range of personality traits with characteristic trends. These engineers were emotionally stable and usually free of neurotic and psychosomatic symptoms. Impersonality was one of their traits, with harmonious but casual interpersonal relationships and normal social participation. Interest in people was rare. The engineers tended to avoid introspection and self-examination, were relatively insensitive, and tended to possess shallow insight. They were further characterized as matter-of-fact, unimaginative, energetic, goal-oriented, serious-minded, conscientious, straight forward, and self-sufficient.

The Allis-Chalmers study (5) used the Bernreuter to investigate the personality traits of successful engineers in different fields of engineering. Average general adjustment was found for design, manufacturing, research-and-development, and erection engineers. Successful sales engineers made a high adjustment score. On self-sufficiency, all groups rated high except design engineers, who were average. Introversive traits were low for sales and manufacturing engineers, high for design and research-and-development engineers, and average for erection engineering specialists. Social dominance was high in sales, manufacturing, and erection engineers; average in research-and-development engineers; and low in design engineers. The confidence scores of all engineers were high. As for sociability, sales engineers were characterized by a high score on this trait, manufacturing and erection engineers scored average, and design and research-and-development specialists low.

Sales engineers, supervisors, administrators, clerks, and miscellaneous groups were not differentiated in Rieger's study (162), using the Rorschach test to investigate occupational personalities. Engineers tended, however, to show less interest in people than did other groups. Rieger concluded that no single personality type is associated with any of these occupational groups.

Small groups of engineers, commercial artists, clergymen, social workers, and insurance agents were studied with the Rorschach by Harrower and Cox (94), who found some qualitative differences. In another paper based on small groups, Steiner (185) reported the most clear-cut occupational personality in engineers, advertising copywriters, and commercial artists. In summarizing the literature she concluded that there are differences of opinion concerning the existence of occupational personalities, and that the Rorschach has yielded both positive and negative results.

In a study of successful engineers, using a personal data questionnaire and a projective technique, Moore and Levy (146) found this occupational group independent and self-directing, with a positive attitude toward authority. The typical engineer was seen as an authoritative person with few intimate friendships, strongly work-oriented, orderly, competent and energetic, and preferring to deal with objects and things rather than with people. He was tense and irritable, with high standards of ethics, and was interested in his career and his family.

Conclusion. Engineers have been found to differ from other occupational groups, students and adults, in their personality traits. They are characterized as emotionally stable, self-sufficient, socially introverted but not introspective, self-confident, conforming, object- rather than person-oriented, casual but competent in interpersonal relations. Personality has been shown to have a bearing on success in engineering training. Engineering students who do better work than their intelligence level would suggest are high in caution, inhibition or control, and the needs to achieve, to gain status, and to improve themselves; low in dependency and resistance to restraint.

INTERESTS AND VALUES

It has often been assumed that interest affects achievement, and indeed, in a factor analysis of mental abilities in the freshman engineering curriculum, Sisk (179) found a factor common to practically all courses in the curriculum. This factor was tentatively termed an interest or study factor.

According to a study made by Holcomb and Laslett (98), an interest inventory such as the Strong Vocational Interest Blank will identify extreme cases of lack of interest in engineering. They concluded, however, that this test cannot be used as a predictor of college engineering success. Long and Perry (126) studied the relationship between the four-year college grade-point average of engineering students and ratings on the Strong and Kuder inventories. Correlations between grades and the Strong were low and statistically insignificant even for the engineer scale.

Melville and Frederiksen (144) investigated the relationship of achievement in freshman engineering students to scores on the Strong. Low but significant correlations with freshman grades were obtained: positive correlations with the psychologist, mathematician, physicist, chemist, and mathematics–physical science teacher scales, and negative relationships with the banker, mortician, and real-estate salesman keys. Those whose achievement exceeded the prediction tended to have interests characteristic of men in the scientific professions. The correlations of the interest maturity, occupational level, and masculinity–femininity scales with academic achievement were less than .20. The authors concluded that the Strong has some limited usefulness as a selection tool for engineering students.

Despite the last study, interest inventories are not generally considered useful in predicting educational success. Strong (186), however, has found the Vocational Interest Blank predictive of academic retention or persistence, as have others in studies such as one by Pierson (155) and one by Sadler (172). In a comparison of students who remain in the engineering curriculum with those transferring out, Sadler reported significant differences between the measured interests of these groups using the Strong. The continuing engineer group had interests like those of successful engineers and chemists, whereas the transfers did not. The majority of the engineer group had interest patterns in the professional physical science group, whereas the transfer group had a pattern of practically no interest in this area.

The work of Berdie (15) suggests that satisfaction with a training program may be more a function of ability to do well than of interest in it. Berdie found no relationship between the engineer scale of the Strong Vocational Interest Blank and satisfaction with the engineer curriculum. The only significant measure of satisfaction with the engineering curriculum was high school rank.

Correlations between grades and the Kuder in the Long and Perry study (126) were very low. But those for the mechanical, computational, scientific, and artistic interests scales were significant at the 5 per cent level, and the literary scale was significant at the 1 per cent. The authors also reported that Kuder-inventoried interests, unlike Strong scores reported in other studies (186, 186a), varied considerably from freshman to senior year, suggesting an instability of interests as measured by the Kuder at this developmental stage.

The vocational interests of engineering and non-engineering students were studied by use of the Kuder Preference Record by Speer (183). He found two somewhat vaguely differentiated engineering groups. The mechanical, chemical, civil, and electrical engineers appeared to form a definite scientific engineering group as opposed to nonscientific engineering groups of industrial and fire-protection students. Scientific engineers are high on the computational, scientific, and mechanical scales, low on the persuasive, and average on the other scales. Nonscience engineers are high on the computational and persuasive scales, average on mechanical and scientific scales, and low on the others. Research engineers appear to be a distinct subgroup and, with chemical engineers, rank highest on scientific interests.

Some years prior to Speer's study, Estes and Horn (61) had investigated interest patterns as related to fields of concentration among engineering students. Their own scoring scales for Strong's Blank, designed for differentiating engineers in different fields of engineering, correlated significantly with the original Strong engineer scale in the case of mechanical and electrical engineers only. Negative correlations of —.09, —.27, and —.63 were found between the Strong engineer scale and the scales for civil, chemical, and industrial engineering respectively. The interests of liberal arts students appear to be similar to those of successful individuals in the social science, business, and literary fields, including such occupations as YMCA secretary, social science teacher, banker, office manager, real-estate salesman, advertising man, and lawyer. The engineers, on the other hand, have interests significantly dissimilar to those of successful individuals in these fields. Significant differences in favor of the engineers exist in the physical science and technical fields, on the scales for engineer, chemist, production manager, farmer, carpenter, printer, policeman, and mathematics–science teacher.

In another study of students preparing for five selected occupations, Blum (20) reported that engineers scored high on the scales for physical science occupations on the Strong Vocational Interest Blank. Mechanical engineers appeared to have the lowest occupational interest level of the five groups studied. Blum also found low correlations between interests and personality traits. He concluded that the greatest differences among the five groups were in their vocational and nonvocational interests, rather than in personality traits, and that there appeared to be little in common between these two variables. Significant differences in interest patterns of engineers and draftsmen and of successful and unsuccessful engineering students were reported by Barnette (10), who also noted that engineering students seemed to earn lower persuasive interest scores than do employed engineers. Whether this is the result of the eventual elimination of engineers who lack such interests, or of change with experience, is not known.

Employed engineers were studied by the Allis-Chalmers project (5), using the Kuder Preference Record. Table 1 summarizes the findings for the various fields of engineering. The expected trends were revealed.

A few studies attempt to investigate the values of engineering students and engineers. Harris (90) studied a university population to assess the values of different academic groups using the Allport-Vernon Study of Values. He showed that engineering and business students scored lower than arts students on theoretical and aesthetic values and higher on political (prestige) values, a finding in line with observed differences in these student groups.

In a study of differences in values among the various specialties in engineering students, Karn (106), using the Allport-Vernon, found reliable differences among his groups of civil, metallurgical, electrical, chemical, and mechanical engineers for all values except theoretical and social. Mechanical and metallurgical engineers deviated positively on the economic scale. Electrical engineers deviated negatively and significantly from all other groups on political values. Generally, metallurgical engineers were the most deviant group and chemical engineers the least. It is significant, however, that Raylesberg (158) reported great variations in engineering students' perceptions of the values attainable in engineering. The values perceived tended to be associated with their own values.

The social orientation of freshmen engineering students and practicing engineers was measured by Speer (182), using the Kuder. He found that the typical freshman engineer lacked social interest, but the typical practicing engineer showed (presumably as a result of employment and subsequent experience), a greater awareness of social situations. Speer concluded that engineers do have interests in social institutions and the improvement of welfare, but do not possess a personal interest in people as individuals.

TABLE 1

KUDER INTERESTS OF EMPLOYED ENGINEERS

FIELD OF ENGINEERING	AREA OF INTEREST								
	Mechanical	Computational	Scientific	Persuasive	Artistic	Literary	Social-Service	Clerical
Design	Very high	High	High	Medium	High	High	Very low	Low
Sales	High	Medium	Medium	Very high	Low	High	Medium	Low
Manufacturing	High	Medium	Medium	High	Medium	Medium	High	Low
Research Development	High	Medium	Very high	Low	High	High	Low	Very low
Erection	High	Low	Medium	High	Medium	Medium	Low	Low

The motives of engineers were studied by Bennett and Drucker (14). Interests in the field of engineering, security, and felt aptitude for the field ranked high as motives. Altruism, gregariousness, and parental influence ranked low. Faculty and students agreed rather well on students' reasons for studying engineering. In another study, however, Pepinsky (153) found a wide gulf between student expectations of their engineering training and faculty aspirations for them. The former looked forward to operations jobs in managerial or sales work, whereas the latter wanted students to aspire to high-level research. The discrepancy may be a result of differences in engineering schools.

The Harrison, Hunt, and Jackson (92) study of adult mechanical engineers characterized them as having strong mechanical and technical interests which tend toward immediate application rather than toward science and research. They appear to have masculine interests, as illustrated by fondness for sports and active outdoor pursuits, with a restricted scope of interests relative to intellectual potentialities. In a personality assessment of these same men, using interviews, questionnaire, and projective techniques, Harrison, Tomblen, and Jackson (93) also found that mechanical engineers possess the masculine traits and interests commonly associated with that field.

Conclusion. In his summary of studies of engineering school prediction, Stuit (188) reported that interests typical of successful engineers are an essential qualification for this field. We have seen that such interests have some slight bearing on success, but they have considerable bearing on persistence in the field. Engineers are characterized by high technical and mechanical interests and low interest in the social science and aesthetic fields. Specialty groups within engineering can be differentiated by interest inventories. The interests of engineers tend to be limited in scope, and practical rather than theoretical.

MISCELLANEOUS FACTORS

In a study of employed engineers, Mandell (132) showed that more of the engineers who were rated low in job performance had graduated from high school at age sixteen, and that athletic participation was related to low job performance.

SYNTHESIS

INTELLIGENCE

In the studies reviewed, engineers were found to possess superior general intelligence of a rather wide range, extending from high average to very superior. As measured by traditional tests, this factor is a fairly good predictor of success in engineering school. Verbal intelligence again has a wide range, tending to be superior. The suggestion is made that this ability becomes more essential to the engineering student as he advances in his work. He seems to be a better deductive than inductive reasoner. Tests of verbal ability, such as reading, English, and verbal analogies, appear to be fairly good predictors of engineering academic success.

Quantitative ability is generally considered to be an essential qualification for success in the engineering curriculum. Engineering students and engineers tend to be superior in it. Tests used to measure this type of aptitude yield correlations with engineering academic success which range from very low to substantial. Such variables as general intelligence, verbal facility, and reading ability have been found in some studies to yield higher correlations with academic engineering success than quantitative aptitude, perhaps as curriculum content and teaching methods vary.

SCHOLARSHIP

Engineers appear to be good scholastic achievers. Grades in high school, high school rank, and success in courses in mathematics and science yield moderately good correlations with success in a school of engineering. It is generally accepted that engineers must have demonstrated superior achievement in high school as a basis for college work.

SPECIAL APTITUDES

In addition, engineers must have fairly good spatial visualization, although this factor is less essential in some fields, such as sales engineering. Measurements of this aptitude have generally yielded only modest correlations with success in engineering training. At least average mechanical comprehension appears to be essential for engineers, but this variable also yields modest correlations (infrequently exceeding the .40's but useful for prediction in

PERSONALITY

a regression equation) with success in engineering training. Other complex and poorly defined factors, such as analytic reasoning, organizational ability, and ingenious practical thinking, are also mentioned as desirable traits of engineers.

In the area of personality, engineers have been characterized by many general traits which lead to success in most other areas of work. Tact, interest, initiative, leadership, dependability, self-direction, competence, and energy are desirable attributes. Engineers emerge from most more scientifically made personality assessments as rather stable, self-sufficient, socially conforming, impersonal, socially introverted but not introspective individuals, thing-oriented, prestige-seeking, casual but competent in interpersonal relationships.

INTERESTS

The interests of engineers appear to be high in the mechanical, scientific, and computational areas and low in the clerical and social service fields. Interests similar in type to those of successful engineers tend to characterize engineering students. Both tend to be narrowly practical, but the interests of the latter are even more limited in scope than those of the former. These interests, while not highly predictive of success in engineering school, do tend consistently to predict choice of engineering, persistence in training, and stability in an engineering career. The motives for choosing engineering as a career are basically interest in this field of work, desire for security, and felt aptitude for the work.

Chapter V

AN EVALUATION OF THE RESEARCH AND ITS MAJOR OUTCOMES

THE preceding three chapters have been devoted to a review of the representative literature on natural scientists, mathematicians, and engineers. In these reviews an attempt has been made to synthesize reported results in order to provide a picture of the worker in each of the fields being studied. This chapter aims to evaluate the accomplishments of this research, using the work on natural scientists —the most extensive—as an illustration, and to view the fields in some perspective.

A GENERAL EVALUATION

The extensive nature of the literature is impressive. Obviously, success in scientific training and careers has not been a neglected area of research. The studies cited are only a selected fraction of a much larger number of investigations of choice of and success in scientific pursuits. The number of these studies is a clear indication that research workers are aware of the importance of the problems of vocational development and of the identification of scientists, but the perspective has been inadequate.

The diversity of the disciplines represented by the researchers and by the methodological approaches to the problems investigated is noteworthy. Natural scientists, biographers, sociologists, psychologists, psychiatrists, and educational administrators have all been involved in a search for an understanding of what makes a scientist. The methodological approaches vary greatly, from biographical study and logical analysis to the more commonly accepted psychometric approaches of objective and projective devices and refined statistical procedures such as factor analysis. But too often the focus has been solely on intellectual or superficial cultural and personality factors. Too often methods have been poorly used.

Theory has not been lacking, for the literature indicates some basic conceptual thinking. A large segment of research is predicated on the theory of individual differences: differences in aptitudes, interests, personality, and socioeconomic status. This has often led to a static, actuarial approach using fragmentary data. But the literature has recognized the dynamic qualities of socioeconomic, cultural, and other environmental differences. The impact of social forces and institutions, such as the school, the family, religion, and the ethnic group, on the process of vocational development and choice has had some consideration. The role of personality development as a determinant of the choice process has also been acknowledged.

Some valid tools for use in the identification and selection or counseling of future scientists have resulted from the above approaches. We have fairly meaningful normative data for some tests. However, the occupational categories are often poorly defined and the ranges are wide for such factors as intelligence and other aptitudes. These contribute to moderately accurate predictions of success in scientific study and employment. Patterns of interest of successful practitioners in the scientific fields, predictive of stability and persistence in a field, have been established and related tests have been developed. Although far from definitive in the personality area, research has provided tentative personality portraits of some types of scientists. The development of selective devices for professional and scientific schools has contributed to a reduction in academic failures with concomitant waste of resources, both educational and human.

New developments manifest themselves in the literature, indicating that there is vitality in the field. There is an emerging shift in emphasis from a static group-differences approach to a more dynamic developmental approach. With this new approach there has emerged in the literature a greater emphasis on social forces and personality determinants. Long widely recognized as basic factors in human development, they are now being examined as determinants of vocational development.

The work done by researchers in the past charts the way for the future. The pioneers in any field enjoy the clear advantages and limitations of original thinkers. What has proved useful in their work is incorporated into the thinking of their successors. Limitations and defects pave the way for improvements. It is to these suggested improvements that this chapter is devoted.

THE NATURAL SCIENTIST AS PORTRAYED BY THE RESEARCH

This section is devoted to a critical examination of the literature on the natural scientist; its research approach, research method and design, and the factors investigated. Specific reference is made here only to the research on the natural scientist, as the most extensive, but these comments apply equally well to work dealing with the engineer and mathematician.

General characteristics of the natural scientist

Attempts to understand the successful natural scientist in terms of general characteristics (such as were surveyed in the initial section of Chapter II) appear to be doomed to failure. The characteristics which have attracted the attention of such observers are so broad and so generally desirable as to be of little differential value. The traits described in the literature appear to apply with equal validity to the scientist, the artist, and the humanist. Such traits as self-discipline, courage, tolerance, enthusiasm, versatility, attentiveness, thoroughness, and alertness are likely to be important to success in scientific fields and in many other types of occupations. For identification and selection purposes there is need for a list of differentiating traits, such as may be derived from comparison of one occupational group with a general group.

It appears questionable whether attempting to characterize the "natural scientist" serves our purpose as well as a more refined occupational approach. It may clarify the picture to divide this broad occupational category into biological and physical scientists, and into specific scientific fields, such as chemistry, physics, and biology. It may even be desirable to subdivide each field into a specific level and type of operation or functioning, such as original researcher, research associate, research assistant, teacher, practitioner, and technician.

The lack of quantification in the language of the general characteristic approach limits its usefulness. Such adjectives as "high," "superior," "frequent," "infrequent," and "much" are often loosely used. Since such words do not permit quantitative description, one is not at all sure of the degree to which the general characteristic is required.

The methods used in obtaining and treating the data are often subjective and nonquantitative. Observations are casually made, experience is analyzed in recollection from the armchair, and so on. It is odd that scientists should be so unscientific in studying the scientist!

The characteristics are often ascertained by biographical study or by the use of a questionnaire designed to enable the researcher to reconstruct earlier aspects of the life of the person being studied. The reliability of these procedures is questionable on two counts: the tendency of most biographers to stress desirable traits, and reliance on memory as a source of data.

Finally, one is impressed by the neglect of a theoretical framework in the literature using the general characteristics approach. Why the factors are important, how and when they developed, what factors contributed to their development, why they operate as they do, and how they are best to be determined remain generally unasked and unanswered questions.

All this approach yields, then, is the knowledge that the successful scientist is believed to be characterized by many qualities which are generally accepted as prerequisite, in some degree, to success in a great variety of fields of endeavor.

Intellectual factors

The literature on the intellectual components of scientific talent or on the intellectual determinants of scientific achievement may also be criticized along these lines. In reviewing the role of general intelligence, it is commonly reported that a high IQ, superior intelligence, or high general intelligence is prerequisite to success in the scientific field. But again, specification and quantification are needed. Where general intelligence is quantified, the variety of fields and the range of ability are often so extensive as to preclude real usefulness. Wrenn (224), for example, found a raw score range on the ACE equivalent to an IQ range of 115 to 167 in his subjects, who were Ph.D.'s in a number of fields, not necessarily successful scientists and not in any well-defined occupation. Roe's studies (164, 165) of eminent scientists revealed a high mean intelligence but considerable dispersion. Her conclusions tell us that scientists achieve eminence with quite varied mental equipment, but they do not indicate the minimum mental ability level producing a worth-while number of eminent scientists. A critical minimum intelligence test score for each specific field and level of scientific endeavor would appear to be desirable. This would indicate how much of what kind of general intelligence is necessary to function as an individual research chemist, for example, working on an abstract problem as opposed to a team technician engaged in a routine scientific task. This also may prove to be a deceptively oversimplified approach, but only properly designed research can yield the answers sought.

This latter observation appears to be particularly pertinent to verbal and quantitative intelligence. Harmon (88) found differences in verbal and quantitative ability in various types of scientists. Roe (165) reported an extremely wide verbal ability range for her group of eminent physical scientists. Adams and Mandell's (3) study shows that verbal tests did not contribute significantly to the selection of physical scientists. They also found that a test of quantitative ability was useful in selecting engineers, but less satisfactory when used with chemists and physicists.

Perhaps the restriction of the range of ability resulting from attrition in graduate school minimizes the effect of intellectual differences in graduate scientists. Was Wrenn justified in assuming (224) that if a scientist is intelligent enough to complete a doctorate, he is intellectually capable of eminence? Is getting over the M. A. hurdle enough? How high on the IQ scale are these degrees? Here again the questions appear to be how much intelligence, what kind of intelligence, and for what level of work in what field of science? In determining the relationship between intelligence and scientific achievement, a general approach does not appear to promise much useful information. The need for greater specificity of both variables, intelligence and occupation, is clearly indicated.

The criteria of scientific achievement used in many studies appear to be inadequate. A common criterion is academic grade or success on an achievement test in a scientific subject-matter area. The relationship of these intermediate criteria to ultimate success in the field is not certain. Correlations between success in training and success at work have been shown by Ghiselli (76) to be very low for most other types of occupations. Follow-up studies carried through to the years of maximum productivity would appear likely to furnish data to which the intellectual factors might more meaningfully be correlated. Where functioning on the job is assessed, the use of criteria which are or may prove to be unreliably derived or basically inappropriate often minimizes the value of a study. Supervisory ratings, earnings, and rank are criteria which may reduce the adequacy of a study of scientists. The difficulty of establishing criteria of scientific success has been indicated by Flanagan (66), who made recommendations for future work in this area and suggested working principles and conclusions based on his own research.

Finally, the criticism that much of the work lacks an adequate theoretical framework is valid also in the intellectual area. Many studies sustain the logical hypothesis that scientific achievement is in part a function of intelligence. But this is one specific hypothesis sometimes juxtaposed with other isolated hypotheses, none of which are bound together by theory. The theory that individuals differ in specific significant respects (the common theoretical basis of studies in occupational ability patterns) provides no overarching theory to suggest and organize these specific hypotheses. Few studies are concerned with reasons for expecting any one or more constellations of factors to be important, or with the dynamic or developmental interplay of these variables.

In reviewing the literature, one gets the impression that the role of intellectual factors in choosing and succeeding in the scientific fields has been studied at the expense of other presumably relevant factors. A large proportion of the studies focus on intelligence and academic success in science courses. These are important in specific college selection programs, but they add little to understanding science as a career. The ease of measurement and quantification of this one variable (intelligence), its importance in achievement, and the needs of college admission programs have resulted in a continuation of studies of this one type of factor and measure. Why some intellectually endowed students turn to the physical sciences, others to the social or behavioral sciences, and still others to the humanities and arts is not well understood. Nor is the character of this turning process clearly indicated. Work remains to be done in developing a theoretical framework which will hold together a meaningful set of hypotheses concerning the various determinants of the choice of a scientific, or any other, career.

Special and complex scientific abilities

In the case of aptitudes which are relatively clearly defined, such as spatial visualization, tests produce moderately good results for certain kinds of scientists and poor results for others. Thus it is important to ask, What kind of special ability for what kind of scientific work? Cases in point are manual dexterity and manipulative ability, which have been suggested by some as required for success in science, but the actual significance of which is quite doubtful.

Complex but, so far as psychometrics are concerned, strictly hypothetical intellectual factors, such as sensitivity, ingenuity, originality, creative ability, analytic power, formulation, planning, designing, interpreting, redefinition, and flexibility are more easily described in the observational and introspective literature than measured in scientific research. This is a shortcoming of the studies which deal with these presumed components of scientific ability. With rare exceptions these traits are named or described rather than operationally defined. Notable exceptions are the work of Flanagan (67), who, by means of job analysis, established critical requirements and designed test items to measure such requirements; and Guilford's (85, 86) attempts to factor-analyze these complex talents.

This brings up a generally neglected type of work on scientific careers: the development of job analyses of occupations at different levels and in related fields, to make possible the identification of specific critical requirements for these jobs and their subsequent measurement and validation.

The absence of a theoretical system in which these variables are believed to operate is again noteworthy. How these special and complex abilities interact and how they combine with other factors in the choice of scientific careers has occasionally been investigated in practice, but is virtually unexplored in theory. Why these abilities are directed to nonscientific fields in some cases and to science in others is also largely neglected.

Personality factors and character traits

Personality factors in careers in science have been recognized as important variables by many researchers. Some analyses of biographies describe natural scientists in terms of broad personality traits, such as goal-integration, perseverance, self-confidence, and absence of marked feelings of inferiority. These traits also seem to characterize successful practitioners in many nonscientific fields. Such self-expressive needs as the desire to excel and to dominate, and such other traits as enthusiasm, industry, and self-control may be criticized on similar grounds. These traits are generally reconstructed on the basis of biographical study and of questionnaires, an approach which yields little more than some specific hypotheses for possible research.

Studies of personality based on the personal experiences of teachers with students and of personnel workers with employed scientists tend to use descriptive terms, such as curious, introverted, courageous, tolerant, and honest. They add little other than a few specific hypotheses to our understanding of the scientist as contrasted to the nonscientist, partly because the terms are not defined in ways which make possible quantitative comparisons.

The personality inventory and self-assessment approaches to personality study appear to be methodological improvements over the subjective analysis of biographies and of personal experience discussed early in this chapter. In too many cases, however, these measuring instruments lack demonstrated validity. It is therefore hardly surprising that what emerges from many of these studies is the kind of general personality characterizations which do not clearly differentiate the natural scientist from members of other types of professions.

Projective assessments of natural scientists are relatively few. Roe's studies, and those by Teevan and Knapp (reviewed in Chapter II) come to mind most directly. The projective instruments used were the Rorschach, the Thematic Apperception Test, and the Blacky Test. Whereas Roe (165) found personality patterns for the eminent scientists she studied, and even suggested that personality varies somewhat with specialty in a field (experimental as contrasted to theoretical physicists), Knapp (108) found that the Group Rorschach (often less sensitive than the individual form) did not differentiate among his three groups of science students, social science students, and literature and humanities students. Roe's findings suggest a certain psychodynamic pattern involved in the choice of a scientific career and successful functioning therein which may be described as eventuating in a poor (withdrawing but otherwise effective) social adjustment, although there was little internal disturbance. Teevan (197) and Knapp (108) reported the lowest over-all disturbance score on the Blacky Pictures among the undergraduate science majors. Certain personality characteristics of these groups are thus established. Feelings of independence from parents are suggested by both Roe and Knapp, as are control, intellectualized emotional energy, and lack of aggression. One cannot conclude, however, that the projective approach to the personality assessment of the natural scientist in these few studies has provided a clearly defined personality portrait.

This observation raises the general question of the desirability of investigating the personality of the "natural scientist." As mentioned above, studies such as Roe's indicate the existence of personality structures more appropriate for some scientific fields than for others, and even suggest personality differences between specialties within a scientific field. This calls for refinements in the selection of scientific specialties and samples to be studied, using the field-level approach. The need for the further improvement of measuring instruments and assessment methods for differential purposes needs no elaboration here.

The lack of control of other variables when personality is being assessed presents problems. Factors such as age, experience, training, and intelligence are frequently not controlled, with consequent contamination of the personality variable. This criticism appears to be applicable, too, to studies of socioeconomic and other cultural factors which have been shown to bear some relationship to vocational choice. There is a tendency to limit attention to the one type of variable of greatest interest to the investigator.

The relationship of factors such as motivation, drive, and persistence to the choice of and success in a scientific career remains to be established more clearly and objectively. Most researchers agree that these factors are probably as important as the intellecual factors. But the measurement of these personality factors and of their relationship to types and levels of occupations in science appears to be an insufficiently worked area of investigation.

Thanks to the rapid development of personality theory, beginnings have been made toward providing a theoretical framework for the investigation of personality factors in science. Roe (169) suggested the importance of parent–child relationships, Kubie (119) emphasized the role of unconscious forces in the selection of a scientific career, Brandwein (28) postulated the interaction of personal, predisposing, and activating factors in molding the future scientist, and Super (192) and Tyler (206) have suggested self-concept and role approaches which, like the others, have yet to be systematically applied to occupational groups. As yet, however, no well-rounded theoretical approach to scientific careers which presupposes a developing organism in a complex environment has been developed.

Interest factors

The assessment of scientific interest has generally been done by the analysis of biographies, questionnaires, personal observation, and interest inventories. The last-named method has been most productive, but the other techniques have yielded useful data on manifest interests. There appears to be general agreement on the following: (1) early interest in science tends to manifest itself in the natural scientist; (2) this interest takes the form of a scientific hobby or activity concentrated in one or two well-defined fields; (3) there is generally some constancy between early and later interests; (4) various types of natural scientists (students and adults) are differentiated from one another and from other occupational groups by their inventoried interests; (5) interests are not generally predictive of performance; and (6) interest is predictive of occupational choice and stability.

The literature is not very clear as to when this scientific interest first develops or the circumstances under which it develops. However, the evidence shows that such an interest generally develops early in adolescence and stabilizes late in adolescence or early in adulthood. What causes it to change when it does change is not so clear, but maturation, new experiences leading to modified self-concepts, and changed occupational concepts may be important factors.

The concept of scientific interests has been shown to be most helpful when refined to denote interest in specific fields of science. Strong (186) has devised separate keys for various types of physical and biological scientists, with intercorrelations of these scales low enough to justify placing them in separate categories. Interest scales for specialties within a field have been found possible and useful with advanced students. Interest appears to develop later in some areas of science than in others.

Interest studies have tended to be limited by lack of control of related variables when large groups were studied. Intelligence, personality, socioeconomic, and cultural variables are generally not sufficiently controlled or analyzed to permit a more exact assessment of the relationship of interest to scientific choice and achievement.

Finally, the purely eclectic pragmatism of most studies of the relationship of interest to careers in science or in other occupations is noteworthy. Efforts have been expended on the measurement of vocational interests, but it is understandable that only after measurement problems were solved and good instruments became available did the nature, origin, and development of interest begin to command much attention. Investigators in this area have tended to work on specific empirical questions. The systematic approaches of Bordin (22), Carter (36), and Darley and Hagenah (45) have only recently begun to bear fruit, and they have not focused on scientific occupations.

Socioeconomic, cultural, and religious factors

Studies dealing with socioeconomic variables affecting the choice of careers in natural science have been almost exclusively concerned with the socioeconomic position of the scientist and his family. Not only has this been a rather one-sided approach, but the treatment of these variables has been static. Almost all studies identify the socioeconomic origins of scientists and of eminent men as predominantly middle class with a tendency toward somewhat superior parental background in terms of education and occupation. It is insufficiently recognized that socioeconomic status is a dynamic factor often characterized by actual or desired mobility, and that the direction of this mobility perhaps as much as the status itself may be a determinant of choice of a scientific career. The static nature of the investigation of socioeconomic variables results from the method of determining this index at a given time rather than over a period of time. Most studies assign status solely on the basis of objective criteria such as the father's occupation, rather than dealing also with the individual's perceptions of his status.

Religious factors have been dealt with occasionally in the literature. Protestant predominance among eminent scientists in the United States, particularly in the case of the more liberal denominations, appears to be confirmed, with a paucity of Catholics in the field of scientific research. Jews appear to be under-represented in one study cited and over-represented in two others. Perhaps the members of minority religions feel less free to reveal their religious affiliations than do members of the dominant religious group. Another possibility is that religious groups which tend to encourage independent inquiry on the part of their members in some areas thereby encourage inquiry in general. It is also possible, since Protestantism is the religion of the descendants of the majority of earlier immigrants to America, that these trends reflect the influences of socioeconomic status and education. The implication here is that religious and cultural pressures and values may well be among the determinants of both the kind of work engaged in and the chances of achieving eminence.

With respect to geographic origin, the results suggest the desirability of further investigation of the psychological and social variables underlying the geographic differences. The evidence is rather clear that some regions generally are not so productive of natural scientists as other regions. But some persons in the former regions become scientists. A study of the ways in which they differ from others in those regions and resemble scientists from other regions may be revealing. Studies of urban–rural origins are somewhat contradictory, but both types of localities seem to produce their share of natural scientists.

Family structure

Position in the family is another commonly studied factor, with the general finding that the natural scientist tends to be the only or oldest boy. This finding has so far been treated as a rather static variable, with little attempt to explore the dynamics of family relations. It would be interesting to determine whether, when a son other than the only or oldest son chooses a natural science career, a pattern of family interaction exists similar to the one prevailing in the case of the only or oldest son. The nature of personal interaction in the family in relation to vocational choice would appear to be a fertile area for research, now that the scientist's position in the family has been shown to be a factor.

Age and sex factors

The age of first evidence of interest in and decision to pursue a scientific career has been investigated in many studies. Early commitment to science appears to be characteristic. However, the age range is rather wide, extending from age ten as the year of first interest in science to the junior or even senior year in college (age twenty or twenty-one) as the age of decision to enter the natural science field. The relevance of the terms preference and choice at these two different life stages (with preference the more appropriate concept at the younger age level and choice at the older level) strongly suggests that a developmental approach to the process of choice would be fruitful. In general, such a research approach has been conspicuously absent. Longitudinal studies beginning at a relatively early age and extending over a period of some ten to fifteen years seem called for, with precise definitions of terms.

Other studies deal with aspects of age tangential to this review, such as the age of maximum productivity. These are important and intriguing problems, but they are not central to vocational choice and are not dealt with here.

Sex as a factor in scientific interest, in the choice of a scientific career, and in achievement is treated in very few studies. The differences in the vocational choices of boys and girls are generally noted and viewed as culturally determined. The implication appears to be that little can be done to the culture to modify the situation. Tyler's studies should be valuable in this connection, and Ginzberg's work on womanpower should be a welcome contribution. The paucity of careful investigations in this area is all the more surprising when one considers that women may be a major source of scientific manpower, particularly in an age when increasing numbers of women enter careers after their children achieve some independence. A study of successful women who are interested in science should shed light on factors, cultural and otherwise, which are operative in the choice of a scientific career by men as well as women. Investigation of factors in family interaction, role in the family, and personality traits promise interesting findings.

METHODOLOGICAL EVALUATION

The following observations may be made with respect to methods used in investigations of the identification and selection of the natural scientist.

The general characteristics ascribed to natural scientists shed little light on their occupation, as the descriptive terms commonly used do not differentiate natural scientists from other successful professional and nonprofessional workers. In order to make studies maximally useful, there is a need to classify occupations by the field in which the scientist works, and by the level within the field.

The quantitative treatment of even the more precisely defined and measured characteristics such as intelligence and special aptitudes is often inadequate because of insufficiently precise definitions of groups, lack of comparison groups, and incomplete analysis of data.

Methods and instruments are in many cases faulty. There is frequent reliance on the study of biographies and on questionnaire or interview methods to reconstruct data which are then not analyzed quantitatively. More recently, there is frequent reliance on projective techniques which also are often subjectively analyzed.

Cross-sectional studies focusing on a particular point in time without consideration of the sequential nature of the choice process are overly relied upon. This is partly because of emphasis on the actuarial methods which readily utilize trait-and-factor theory, partly for practical reasons, but even more because of the lack of a developmental perspective.

A great many studies deal with factors related to success in the college study of sciences, mathematics, or engineering. While success in courses is a prerequisite to and perhaps a determinant of choice, it should be treated as such, not as an end in itself. Not everyone who does well in a course enters a related occupation. Success in courses is both a criterion to be predicted and a predictor to be studied along with others.

Criteria of scientific success are inadequate in many studies. Academic achievement is easily studied despite the defects of academic grades, while ultimate success on the job is not so easily appraised. Where the latter type of criterion is used, there is a tendency to rely on factors such as salary, rank, and supervisory ratings, without adequate consideration of the appropriateness of the criterion used or the possible need for and advantages of several selected criteria.

Sex and cultural differences in scientific interest and achievement appear to be somewhat neglected. Women and other "minorities" appear to constitute a potential supply of scientific manpower. Therefore, the factors militating against their development as natural scientists, and the factors causing some of them to become natural scientists despite their status and the culture, are worthy of investigation. Studies of this nature may also help to explain the choice of nonscientific careers in the cases of some able "majority" group members.

A theoretical framework is conspicuously absent in most studies. The approach is commonly that of investigation of isolated factors selected on the basis of partial job analyses or previous findings, a fragmentary trait approach rather than a systematic developmental approach. As a result, the findings of such research do not lend themselves to the formulation of a well-organized theory of vocational development in the natural sciences.

Scientific occupations need to be more adequately analyzed, classified, and defined to permit more precise studies and more valid tests of hypotheses concerning occupational choice and differentiation.

THE RESEARCH IN BROADER PERSPECTIVE

So far, in this chapter, the major outcomes of research in the choice of scientific careers have been integrated to reveal the natural scientist as we now know him, and to evaluate methods and instruments used in studying scientific occupations. Careers in the natural sciences have been used as a prototype. It is relevant also to examine such research in an effort to obtain a better understanding of another kind of issue, namely, the type of approach to the study of scientific careers which has typically been used, the advantages and limitations of this type of approach, and some other approaches which might profitably be employed. This closing section of Chapter V reviews the latter type of material, organizing and elaborating upon points made earlier.

The content can be organized under six headings: theory, orientation, topics covered, design, method, and purpose. Some of these require little elaboration, while others need more extended treatment.

THE CONCEPT OF CAREERS AND OCCUPATIONS

Theories Used. The studies reviewed lack an explicit theory of careers. They rarely if ever ask what a career is, or inquire as to its nature. They tend to view careers as synonymous with occupations, as though deciding upon, entering, or being in an occupation were the equivalent of pursuing a career. Focusing thus on occupations rather than on careers with their successive developmental stages, these studies might be expected to have a theory or theories of occupations which determine their approach. Actually, they lack this also.

The theory implicit in the great majority of the studies reviewed is, we have seen, the theory of individual differences. Assuming the importance of individual differences, the investigator typically utilizes explicit or implicit hypotheses concerning the individual traits or factors which may determine the choice of an occupation or success in that occupation. The focus is therefore on the determinants of a specific choice and of success, and the concern is with relevant traits and factors. As it is recognized by many that situational as well as personal factors may act as determinants, some studies give some attention to situational factors. But these are not so numerous as the studies of personal determinants, and they are typically not so thorough in their methods.

A major defect in the theory of individual differences as a basis for research in occupations is that, as noted earlier, it provides no organizing concept. Exclusive reliance on this theory results in the formulation of fragmentary hypotheses. It is hypothesized, for example, that intelligence plays a part in success in engineering training, therefore intelligence tests are used in studies of engineering school success. When this hypothesis is sustained it yields useful information, but it does not suggest directions for further hypothesizing. The imperfect predictions, then, indicate that other factors which are not being measured must be operating. This leads to setting up other hypotheses which are equally fragmentary and independent. But there is no over-all hypothesis to guide the setting-up of specific hypotheses, other than the very general theory that people differ in various ways and that these individual differences have occupational significance.

This suggests that improvements in the planning of research in individual differences as determinants of occupational choice and success might result from formulating general hypotheses concerning vocations, the choice process, and the achievement and adjustment processes. Such general hypotheses would serve as guides in the setting-up of hypotheses concerning the role of specific aptitudes, traits, or factors. This is, in a sense, what job analysis does when its possibilities are fully exploited and result in the development of a picture of the occupation. Occupational descriptions which include material on the social roles of occupations and on the personality structures compatible with these roles may provide good frameworks for more specific hypotheses.

Other Possible Theories. It is relevant to ask what alternative to trait-and-factor theory, if any, exists as a possible framework for studying choice and success in occupations. Super (193, 194) has elsewhere suggested one, in the form of a developmental theory of career patterns. This theory differentiates the concept of a career from that of an occupation, in that the latter is what a person does to occupy his time (typically for remuneration and to sustain himself at any one time), whereas the former is defined as a sequence of jobs or occupations (and of activities preparatory for and sequential to work) throughout the course of a lifetime.

In this framework vocational choice is not treated as an event occurring at a point in time and explainable by determinants which can be observed adequately at that same point in time. Rather it is treated as a process which takes place over a period of time and which is best explained by a combination of determinants which interact, are modified, and thus develop with time.

Orientation

Static versus Dynamic. The orientation of the bulk of research in the choice of scientific careers and of success in science makes the implicit and sometimes even explicit assumption that the determinants of choice and success are static: the IQ is constant, interest inventory scores are stable, social status is static, and so on. The stability of individual differences and the constancy of the environment are central to the use of these types of data in regression equations, and the regression equation is the epitome of the application of the theory of individual differences to the prediction of behavior.

In contrast, a developmental orientation such as is involved in the concept of career patterns and a theory of vocational development, outlined in the first monograph of the Career Pattern Study (196), is dynamic rather than static. It makes the assumption, for example, that intelligence is a product of interaction between organism and environment, that interests also develop as a result of experience, that social status may change with the individual and with social conditions. It hypothesizes that the best understanding of vocational choice and success can be obtained by studying the development and interaction of such factors, by portraying the development of the individual along such dimensions, and by ascertaining the patterning of this development. It further hypothesizes that a better prediction of vocational behavior can result from the analysis and extrapolation of behavior patterns than solely from the actuarial use of trait-and-factor data.

Occupations versus Specialties. The studies reviewed in this report tend to treat occupations as rather broad entities. They deal with chemists, physicists, biologists, mathematicians, engineers. But Estes and Horn's study of engineers (61), Roe's (164, 165) studies of biologists and physicists, and Strong and Tucker's (187) studies of physicians, among others, show that there are sometimes advantages in working with more refined occupational categories such as creative researchers and routine assistants, pediatricians and surgeons, perhaps electrical engineers and sales engineers. Differentiating interest patterns which predict occupational choice and occupational stability have been identified for both occupations and specialties. In view of the failure to identify any clear-cut personality patterns for occupations, and the success of preliminary personality studies of specialty groups, it would be worth ascertaining whether or not there are distinctive personality patterns for specialties (of both field and level) within a given occupation. It seems altogether likely that, once adequate designs and instruments are used, the differing role expectations of specialties will result in the finding of occupational personality patterns.

Topics

Success. The emphasis on traits and factors which characterizes research in occupations has supported a focus on success rather than on choice. Why predict choice, when success can be studied? Colleges want students who will succeed in a field of study, employers want men who will succeed in their jobs. Counselors want to help students and clients choose occupations in which they will do well and find satisfaction. The topic of most occupational research has, therefore, been the determinants of success in various occupations, with methods of ascertaining these determinants. Surprisingly, there has been relatively little study of the nature of success in science.

Choice. When there is a manpower shortage, employers and those responsible for professional training inquire concerning choice. They want to know not only who chooses a particular profession but why he chooses it, and why others do not. Understanding the dynamics of the choice process becomes crucial, for if it is understood, then certain factors may be controlled in such a way as to make human resources more readily available for the meeting of manpower needs. To be specific, if we understand what makes boys and girls become and remain interested in science and scientific occupations, and what makes them decide to enter those fields, we can then organize experiences to which they are exposed in ways which permit the development of scientific interests and the choice of a scientific career.

It thus seems likely that an important change in the topic of much occupational research should be introduced. While encouraging new work in the determinants of success, since many of these are not well understood and measured (particularly the affective), it would be well to encourage more research on the choice process and on the factors determining choice.

Design

Cross-sectional versus Longitudinal. Most of the work reviewed has been cross-sectional in design rather than longitudinal. Test scores are correlated with current achievement records, biologists are compared with psychologists. When a longitudinal design is used, it is typically a correlation of freshman test scores with subsequent college grades, and occasionally a matter of retrospection in filling out a biographical inventory or answering interview questions which are treated with reference to present status. Little work has been done by following subjects who become scientists from school or college to employment, as Terman did (200), or from hiring to regular functioning on the job, as Mandell has (131). But these longitudinal methods have been recognized as essential to good predictive studies as well as to developmental studies.

Age Level. Studies of occupational groups tend to use as subjects members of the occupation or persons in training for the occupation. Such subjects are easily identifiable, somewhat accessible (especially the students) and, if the focus is on success, some sort of criterion is rather readily obtainable. But, particularly in the case of the professions, this means that the subjects have already reached maturity or near-maturity; and it also means that the choice of occupations has already been made in many cases. This may be a good thing, even when choice is the subject of study, for retrospection has certain advantages. But it makes impossible the study of the individual's characteristics, situation, and behavior while the choice process is actually taking place. Certain types of data therefore cannot be collected.

Progress in the study of occupational choice, or vocational development as it may better be called in order to make clear the nature of the process, therefore appears to require studies which begin at lower age levels than most of those which have been located and reviewed. As Ginzberg and associates pointed out (77), this means beginning with subjects between the ages of eleven and fourteen. If personal interaction in the family is to be studied, the age must be lowered to between three and five, as in Tyler's work (206). Some studies of occupational choice have used cross sections at various age levels to simulate a longitudinal design. Others have taken successive cross sections of the same individuals in order to study development. Occasional studies of development have been made by means of virtually continuous observation of the same subjects. But none of these has been concerned particularly with the vocational development of scientists. Perhaps Terman's monograph (200), a by-product of his study of gifted persons, comes closest to being such a study, using as the design the cross section at successive stages of development. Data from some of the well-known longitudinal studies might well be analyzed for the study of scientific careers, thus saving time in the genetic approach.

Control Groups. As was frequently mentioned in earlier chapters, large numbers of studies of scientists have been made without the use of control groups. To know that scientists of some type are introverted helps little unless one knows whether or not they are significantly more introverted than other persons from whom it is important, at some point in their careers, to distinguish them. Thus the crucial comparisons are those of high school sophomores who later become physical scientists with other high school sophomores who do not become physical scientists (especially the nonscientists who go to college), of college freshmen who later enter the occupation with freshmen in the same colleges who do not enter that occupation, of employment applicants who make good on the job with employment applicants who fail on the job. While control groups are not important to all types of studies, the decision not to use them should be made on the basis of superfluousness, not because of failure to see the need or to seek the means.

Contamination. Contamination of the data as a result of poor experimental design or poor planning of analytic methods has rendered the findings of some otherwise important studies questionable. Students who know they are failing may not respond in the same manner as students who will later experience failure. The fact that meaningful results are likely to be obtained only when data are collected before critical experiences, when subjects are not informed of the results of early data analyses, and when the researchers' knowledge of one set of data does not affect the analysis of another set of data seems to have escaped the notice of many research workers or to have been disregarded by them.

Method

The Actuarial Method. The underlying theory and orientation, and the resulting topics and design which have characterized the bulk of the research in scientific careers have in turn dictated the methods of research. They have generally been actuarial. Thus they have consisted of a search for traits and factors which may be significant in the choice of or success in scientific careers, the selection of instruments with which to assess these factors, and the use of a criterion of occupational choice or success with which to correlate the presumed predictor. When biographies and observation have been the sources of traits and factors, no reliability or significance tests have been applied to the results of these analyses.

Trait Selection. The decision to analyze the role of any particular trait, factor, or aptitude in choice or success can be made, as pointed out above, on the basis of more or less clearly formulated hypotheses concerning the nature of the occupation. Sometimes the hypotheses seem to have been dictated more by the nature of an available instrument than by theories concerning the occupation or occupational choice. The fact that the professions require superior intelligence has been overworked in studies of the selection of students, often precluding the selection of other traits to test.

The making of job analyses which yield a well-rounded picture of the occupation and of its incumbents would seem to be a prerequisite to better selection of traits for study.

Instrument Selection. Devices and methods for collecting data have generally involved biographies, observation, interviews, questionnaires, inventories, tests, or a combination of these. An unfortunate stereotyping of research along certain lines has resulted from the availability of biographies (however unrepresentative of a given occupation their famous subjects may be) and the ease of casual observation (however unreliable). Psychologists have perhaps been misled by the warmth of personal interaction in interviews (despite the problems of standardizing and analyzing the data obtained), the ease of administering and scoring certain inventories (whether relevant and reliable or not), and the validity of tests for certain purposes (whether or not appropriate for adding to our knowledge of the occupation in question). Thus the ACE is studied as a predictor of success in professional training, the Rorschach is used by Rorschachers, the MMPI is administered by those who want a "good personality inventory," and casual observation is relied upon as a source of data on careers by natural scientists who know better than to rely on it in their own scientific specialties. Moderately good instruments and devices exist for collecting data on certain types of traits and factors. Intelligence, certain special aptitudes, achievement, interests, and values can be rather well measured. Interview methods can be made reliable, while content analysis can treat the data they collect, observation can be directed and recorded, and so forth. Instrumentation falls down, however, in the assessment of personality factors such as needs, motivation, reaction tendencies, and adjustment. Since it is in this area that we still have most to learn about choice and success in scientific careers, the development of improved methods of assessing personality is imperative.

Criteria. Studies of careers generally seek to answer questions about choice or success. This implies the availability or the derivability of indices of choice and success, that is, of criteria. Personnel research during and since World War II has made clearer than ever the difficulties encountered in the search for reliable, valid, and appropriate criteria (191: 32-43).

How does one define vocational choice? When has a person actually chosen his occupation? Is it when he first formulates a preference for an occupation, when he applies for training leading to it, when he enters the training program, when he has completed the training, when he plans to seek a job in the occupation, when he applies for the job, when he obtains the job, or when he decides after working at the occupation that he will remain in that field? All of these definitions, convertible into indices, have some relevance, some validity. Each may be better for some purposes, worse for others. *Which, when, what for,* and *why* have rarely been considered and never investigated.

And what is vocational success? This has been considered as a problem in occupational research, but rarely specifically for scientific careers. In some studies it is getting a job in the field, or it may be holding the job for a certain period of time, getting raises or promotions, producing much work or producing outstanding work, or being well rated by supervisors or by co-workers. The relative value of these various criteria of success has often been discussed, but better bases for the selection of criteria in various types of studies are needed.

The Developmental Method. So far this discussion of methods has focused primarily on the actuarial or statistical method, which is appropriate for trait and factor data and which is commonly used. Methods appropriate for the developmental approach, exemplified by the work of the Career Pattern Study (196), also need consideration.

How does one collect and quantify data on a process such as that of occupational choice? Typically, such data are collected by successive observations, whether the observations are in the form of interviews, tests, or other devices. The process is described by means of inferences concerning changes from one observation to another. But there are unanswered questions concerning the measurement of change; for example, the comparability of instruments at different age levels and the importance of practice effects. There are unanswered questions concerning the making and validation of inferences regarding processes. Most of the questions raised about actuarial methods also apply to the methods used in developmental studies. Much more could be said on these subjects, but it is appropriate here only to point out the fact that they exist.

Purpose. In closing this chapter, it is well to raise the question of purpose. Given the knowledge that a certain constellation of traits is indicative of future choice of a scientific occupation or of success in a scientific career, what use will be made of the information? One may seek to identify individuals who have these traits, in order to encourage them to enter or to admit them to that field of science. This has been the purpose of most research to date. For this purpose, one may seek to develop better instruments to use in this identification process. Or, one may seek to develop these critical traits in persons who lack some or all of them in some degree, so that they may qualify for careers in the scientific occupation. This has rarely been the goal of the research in this field; perhaps it should be more often. For this purpose, one would study the development of these traits so that ways could be devised for cultivating them more effectively. It may be well to do both of these things.

Given the knowledge that the choice process takes place in certain ways, at certain stages of development, as a result of certain factors, what use will be made of it? Presumably the process may be guided so as to make choice more economical psychologically and materially, more timely, more appropriate for the individual, and more socially useful. The individual as well as society could gain from the reduction of the amount of floundering which characterizes the exploratory experiences of many young people, from the earlier launching of careers, and from the greater productivity which would result from the earlier and more confident clarification of vocational goals.

Chapter VI

THE NEW LOOK IN OCCUPATIONAL RESEARCH, AND AN INTEGRATED APPROACH

THIS chapter will attempt to present the "new look" in career and occupational research and to suggest an integrated approach to further research in vocational development. The method deals with careers in general, with emphasis on higher level occupations. Although it does not deal specifically with scientific careers, it is based in part on Chapter V, in which the conclusions for the scientific occupations discussed in this monograph are pointed out. A summary of that part of this report will be found in Chapter I.

As indicated in the Preface, the contributions of the Project's Advisory Panel members represented three major types of theoretical approaches: trait-and-factor theory, social-systems theory, and personality theory. The major elements of each are reviewed briefly in the following pages. Finally, an integration of these positions is presented. It should be made clear that these theoretical approaches represent differences of emphasis only: each is viewed as a partial analytic system and none as a complete system by itself.

TRAIT-AND-FACTOR THEORY

The trait-and-factor approach characterizes most of the literature reviewed. Based on the theory of individual differences, it concerns itself with individual traits or factors which are believed to determine the choice of and success in an occupation. It may be considered the classical approach. It is, for the most part, a person-centered viewpoint with emphasis on personal traits. Environmental factors such as social status have, however, been studied.

Present-day trait-and-factor theory retains the classical emphasis and suggests certain modifications. It holds that much meaningful information with respect to occupational choice and success has resulted from research on intelligence, aptitudes, interests, earlier achievement, personality, and motivation. It contends that refinement of instruments, sampling, criteria, and statistical techniques can continue to contribute materially to our understanding of vocational development, of occupational choice, and success. It stresses the need for more adequate descriptions of ability requirements, critical cut-off scores related to specific fields and levels, a better understanding of interests and values, and better measures of needs, motivation, and adjustment. It emphasizes the development of a functional approach to occupational classification. It recognizes the fragmented nature of much existing research and stresses the need for comprehensive, coordinated longitudinal studies. It acknowledges the importance of cultural forces, the so-called deeper motives, and the need to understand the whole individual. It accepts developmental concepts and recognizes that different factors are important at successive life stages.

A somewhat divergent trait-and-factor approach[1] rejects the classical position as basically unrewarding with respect to vocational choice. It contends that it is a waste of time to seek further to identify traits which characterize members of a particular occupational group. These occupational groupings are viewed as too broad to permit the establishment of usefully discriminating patterns of ability, aptitude, interest, or personality. It emphasizes, instead, the identification of factors which influence the sequence of vocational decisions or choices and it recognizes that what has often been called occupational choice is actually the product of a succession of choices, each decision being the result of positive and negative influencing factors. These factors represent a combination of social, economic, and psychological forces which result in a choice. Therefore, according to this viewpoint, individual traits and factors should be treated as influences on a series of choices rather than as requirements for specific occupations.

[1] This is essentially the position Dr. Wolfle took in his memorandum for the Panel Meeting.

The present formulation of the trait-and-factor approach may best be summarized by quoting the memorandum prepared by the exponents of this viewpoint who served on the Advisory Panel:[2]

Most of the studies reviewed in the Working Paper [now Chapters II-IV] can be classified as representing a trait-measurement or occupational-group-differentiation approach. In this approach, the usual model is to select a sample of an occupational group, obtain measures of selected characteristics, and either analyze how the group differs from other groups (or from the general population) or determine to what extent the measures are correlated with some criterion of success or satisfaction on a particular job.

The question may be raised as to the value of such studies, particularly since occupational titles frequently cover a great variety of work and since membership in an occupation is the end result of a number of influences operating on a series of career decisions. The effect of these limiting factors is recognized, but it is considered desirable to continue studies based on the theory of individual differences with the expectation of discovering additional useful information concerning the intellectual, interest, achievement, personality, and motivational factors associated with occupational success and satisfaction. The rationale and justification for such studies are as follows:

1. Occupations or fields of work differ in terms of *basic functions performed, levels of difficulty, types of work settings, prestige levels, types of rewards,* and *style of life* associated with the occupation.

2. Success and satisfaction in an occupation are determined, at least in part, by the possession of a limited number of patterns of aptitudes, interests, skills, personality characteristics, values, and so forth. The more generalized the activity, on a scale ranging from specific position, to job, to occupation, to occupational group, the larger the number of patterns applicable to the activity.

3. From 1 and 2 above it can be concluded that programs for the development of the necessary skills and background for successful, satisfying work in a given occupation are dependent upon identification of the patterns of personal characteristics conducive to or predictive of success and satisfaction in that occupation or field of work.

4. An individual is more likely to make wise career choices if he has adequate information about himself, his environment, and the world of work. The specificity of occupational information needed will vary depending upon the developmental level of the individual and the specificity of the career decision being made. These decisions are cumulative over time, proceeding from the general to the specific, therefore requiring increasing specificity of information.

[2] The trait-and-factor committee was composed of Drs. Gustad, Hausman, Stuit, Thompson, and Wolfle at the Panel Meeting.

5. During the early developmental period, family, social, and educational factors constitute broad influences which reduce the total manpower pool from which a given occupational group may eventually be drawn. During this early period, trait-measurement studies will have little value (for guidance and recruiting) in attempting to make predictions of final occupation from measured characteristics. Psychometrics do have an important function during this period, however, in identifying high ability youths so that appropriate steps can be taken to keep them in the high scholastic achievement pool and thereby retain them for later direction toward the professional occupations.

6. With the coming of the educational period when curriculum differentiation begins, that is, junior high school, information on the relationship between personal characteristics and occupational demands becomes more and more important.

7. Studies of such relationships should be tied in with our increasing knowledge of the stages in careers and of the successive choice points underlying these stages. Prediction should be directed toward the next stage rather than to a hypothetical "final occupation."

8. To accomplish the above will require a more functional type of occupational analysis, providing both a broad grouping of occupations in terms of basic functions and also a detailed description of tasks. The former will permit the determination of personal traits and experience variables related to success and satisfaction in a broad field of work. The latter will help the young person to obtain a more realistic understanding of the nature of the occupation under consideration and will facilitate the more specific choices which occur during the later stages of occupational life.

The above rationale for the continued search for the variables and traits which characterize occupations is not dependent on an actuarial or cross-sectional approach, nor is it restricted to test data. It assumes merely that job analyses will reveal important dimensions for the functional grouping of occupations and that patterns of measured variables can be discovered for the various stages of vocational development in a given occupation or field of work. An important first step in the study of scientific occupations is, therefore, the determination by job analysis procedures of whether or not there is a set of common functions which characterize scientific work. Until this has been achieved, there will be no adequate guide for the inclusion of occupations in the field of scientific work.

Further progress in the determination of occupational differences based on the trait-measurement approach will therefore depend upon research devoted to the identification of the basic dimensions along which the fields of work differ, of the basic dimensions along which individuals differ, and of the environmental and genetic factors which influence the development of these characteristics.

SOCIAL-SYSTEMS THEORY

The social-systems approach[3] to vocational development places emphasis upon the dynamic interaction of the individual with the social systems which impinge on him, and upon the interaction of these social systems with one another. It has a great deal in common with the cultural–psychodynamic approach summarized below in the personality section.

The theory is based on the concept of developmental tasks which confront the individual with a need to make certain choices. These developmental tasks are relatively concrete or abstract, differ according to age levels, and are continuous over a period of time. The individual confronted with these developmental tasks and choice decisions may be viewed as occupying the center of several concentric circles which represent the social systems with which he interacts. These systems are instrumental in his decisions and choices. The outer circle represents general American cultural variables (free enterprise, American democracy, Western values, American mores). Moving inward we come to the subcultural forces which exert themselves on the individual (class values, attitudes, customs). The next circle represents community variables (peer relationships, ethnic groupings, religious influences, social contacts). Finally, most directly impinging on the individual are the organizational settings in which he is operating at any given time: his home, school, family, church, and so on. As one moves from the periphery (general American culture) to the center (organizational settings), task requirements generally change from the abstract to the very specific.

This conceptual framework provides the means of postulating a general set of assumptions about an individual's task requirements at certain age levels and about the opportunities available to him to meet these task requirements. Vocational development is thus seen as essentially a compromising or synthesizing interaction between the individual and the social systems in which he operates.

This approach might perhaps be conceptualized in another way,

[3] Drs. Ginzberg, Hummel, Mills, and Pepinsky comprised the social-systems committee at the Panel Meeting.

as in Chart 1[4] below. Here again vocational development is seen as the interaction of the individual with social systems presenting certain vocational developmental tasks and affording opportunities for performing these required tasks. It should be borne in mind that this choice process extends over a period of time ranging from the preschool state to maturity. Furthermore, while the schematization stops here, it is clear that vocational developmental tasks continue into retirement, as outlined by Super and associates (196).

Let us look specifically at the first relevant developmental stage, the preschool. A child is born into a social system. The father usually has some kind of job and earns a salary, the family lives in a certain place, the parents identify with a certain socioeconomic class and have certain attitudes, expectations, and values. The child soon becomes aware of general developmental tasks. He is weaned, toilet trained, learns to be both dependent and independent, and is socialized. Vocational developmental tasks present themselves early as the need for the individual to distinguish between appropriate and inappropriate dependence, the need to move toward independence, the need to accept socialization. Opportunities for vocational development are usually also present at this early stage in the form of environmental exploration, tentative self-direction and independence, learning of parental attitudes and values, and possible parental encouragement of manifest abilities and interests.

A similar analysis could be made of the other developmental stages. The social systems operating at one developmental stage continue to exert their influences on successive stages unless there have been basic changes in the social systems which impinge on an individual. In Chart 1 the more important social influences at any one developmental stage are indicated. These continue to operate during successive stages, although they are not included in the characterizations of these stages. There has been no attempt here to list all the sociocultural factors or all the vocational developmental tasks and opportunities operating at any one stage. The aim has been simply to outline this concept of vocational development.

[4] Professor Hummel conceptualized the interaction of the individual with the social systems in this way at the Panel Meeting.

CHART 1

DEVELOPMENTAL STAGES, WITH ILLUSTRATIVE SOCIOCULTURAL FACTORS AND VOCATIONAL DEVELOPMENTAL TASKS AND OPPORTUNITIES

DEVELOPMENTAL STAGES	CULTURAL EMPHASES	VOCATIONAL DEVELOPMENTAL TASKS	VOCATIONAL DEVELOPMENTAL OPPORTUNITIES
PRESCHOOL	Father's job; father's earnings Parental attitudes Parental values Parental expectancies Place of residence Family status	Learn dependency Learn self-help Learn self-direction Maturational tasks	Opportunity to: React to parental handling, attitudes Explore environment Begin to develop peer relations Begin to develop authority and important-figure relationships
ELEMENTARY SCHOOL	Urban–rural enrivonment Family class identification Religion School	Conform to school Deal with family attitudes Begin to develop own attitudes and values , Choose JHS curriculum Pass school subjects	Opportunity to: Learn about world of work Explore world of work Develop attitudes to school and school subjects Have after-school work experiences

HIGH SCHOOL	Family associates Family attitudes and behavior Values of teacher Class values	Choose HS curriculum Develop study habits Make tentative vocational choices Implement self-concept	Opportunity for: Academic exploration Work experience (summer) Tentative occupational choice
YOUNG ADULT	Courtship and marriage Family finances Availability of college Military service	Postpone gratification of immediate needs Defer marriage Gain college admission Find job Move toward career decision	Opportunity for: Choice of educational major; choice of educational minor Continued academic exploration; change of educational major; job changes In-service training Returning to school
MATURE ADULT	Status in family Economic responsibilities Realties of the market place: war, depression, prosperity, technological change	Vocational establishment and advancement Acquire new skills	Opportunity for: Changes of jobs or fields of work Job promotion Further schooling

PERSONALITY THEORIES OF VOCATIONAL DEVELOPMENT

Exponents of personality theory (who in increasing numbers find careers a fruitful field for theory testing) stress the personality structure of the individual and its dynamic development as determinants of vocational development. This structure is commonly seen as the end product of hereditary, environmental, and experiential variables, with differences of emphasis depending on the importance ascribed to the variables. The more common approaches are derived from theories of psychoanalysis, selfhood, interpersonal relations and needs, and finally a combination of cultural anthropology and psychodynamics. Each is discussed briefly and a synthesis of these emphases is attempted.

A PSYCHOANALYTICALLY DERIVED APPROACH

It is believed by some psychologists[5] that psychoanalytic theory offers a framework for a dynamic, developmental understanding of vocational choice. This form of the theory, however, must deal with processes in the normal individual. It holds that the basis for vocational choice is laid very early in life, probably in infancy and in elementary school. The mechanisms of identification (positive or negative), sublimation, and the process of role implementation are viewed as important determinants of choice. The theory suggests that there are differences in the opportunities for need gratification offered by different occupations, and perhaps even within the various specialties of a given occupation. Needs are in part, at least, unconscious determinants. One must thus seek the many conscious and unconscious forces which interact as basic determinants of the choice process. Hence there is need for psychoanalytic investigation of these determinants. In order to understand the world of work, job analyses are required which reveal the personality demands of jobs as well as the social roles which jobs make possible. One source of data for hypotheses concerning the personality demands and social roles of occupations consists of popular beliefs and stereotypes with respect to occupational personalities.

[5] This is a modification of a view expressed by Dr. Segal at the Panel Meeting.

Self-concept theory

The self-concept theory of vocational development[6] is based on several assumptions. First, all men have the potential to anticipate the future, select goals, and move toward these goals. Some actualize their potential, others do not. All men, furthermore, have the potential to perceive themselves and their environment, but differ in the manner in which they organize these perceptions. Man strives for consistency of thought and action: inconsistency results in attempts to reintegrate thought, to change the bounds of action, or to live with this inconsistency as long as necessary. Learning involves the differentiation of certain components and the reintegration of newly differentiated components with all relevant previously differentiated components. Finally, these differentiations are comprehended in various ways and experiences are integrated differently by different individuals.

Vocational development, then, is the process of forming and perpetuating a self-concept. It is a process concerning which we have but a meager understanding. How an individual's impressions of himself are organized, his awareness of these impressions, his imaginings of the future, and the structuring and restructuring of these impressions to enhance the likelihood of self-realization appear to be fruitful topics for additional research in vocational development.

Vocational choice as the implementation of the self-concept was suggested by Super (192), and is emphasized by Tyler in her adaptation of identity theory (206).[7] The basic questions for the individual appear to be, Who am I? and Where do I belong? In this search for identify as it relates to vocational development, Tyler stresses the exclusion process, which she describes as a rejection of certain vocational fields which clearly sets the limits of future possibilities. The importance in vocational development of such factors as identification, experienced social status, and the judgment of one's potential is emphasized.

[6] This is essentially the view elaborated by Dr. Tiedeman in his memorandum for the Panel Meeting.

[7] This approach was further developed by Dr. Tyler in her memorandum for the Advisory Panel Meeting.

Theory of interpersonal relations and need satisfaction

The process of vocational development according to this theory,[8] is viewed as one of the results of the interaction among hereditary, environmental, and experiential variables. The third group of variables, particularly early experiences in the family, such as parental handling of the young child in need satisfaction, assume major importance. Several general hypotheses are quoted from Roe's memorandum:

1. A limit to the development of somatic, cognitive, and conative elements is set by genetic inheritance.
   a. In the case of the somatic and cognitive elements and, to a lesser extent, of the evolutionary older conative elements, development is limited as to channel or mode as well as to extent.
   b. In the evolutionary younger conative elements, possible modes of expression are less determined genetically and hence open to greater variation, with variation in cultural and experiential factors.
2. The degree and avenues of development of all hereditary factors are affected by aspects of the general cultural background and of the socioeconomic position of the family.
3. To the extent that there is any hereditary basis for interests, attitudes, etc., this basis is relatively undifferentiated and these characteristics in the adult derive chiefly from the early experience of the child.
   a. The particular pattern of interests and attitudes is primarily determined by the directions in which psychic energy comes to be expended involuntarily.
   b. These directions are determined in the first place by the patterning of early satisfactions and frustrations.
   c. The modes and degrees of need satisfaction determine which needs will become the strongest motivators.
      (1) Needs satisfied routinely as they appear do not develop into unconscious motivators.
      (2) Needs for which even minimum satisfaction is rarely achieved will, if higher order, become in effect expunged, or will, if lower order, prevent the appearance of higher order needs and will become dominant and restricting motivators.
      (3) Needs, the satisfaction of which is delayed but eventually accomplished, will become unconscious motivators depending largely upon the degree of satisfaction felt.
      (4) The eventual pattern of psychic energies, in terms of attention

[8] This is essentially Dr. Roe's position elaborated in her memorandum for the Panel Meeting.

directedness, is the major determinant of the field or fields to which the person will apply himself.

d. The intensity of these primarily unconscious needs, as well as their organization, is the major determinant of the degree of motivation as expressed in accomplishment.

The satisfaction and frustration of basic needs are clearly related to the parental handling of children and the psychological climate of the home. Such variables as parental overprotection and pressure, parental rejection and neglect, and types of parental acceptance (casual or loving) are important factors influencing the focus of vocational activity. Experience with such variables, according to Roe, makes for the development of basic attitudes, interests, and capacities which gain expression in the general pattern of adult life, in personal relations, and ultimately in vocational choice, the latter representing the coalescence of the genetic, environmental, and experiential variables outlined above.

Cultural–psychodynamic approach

As the title implies, vocational development in this approach[9] is viewed as a result of subcultural factors interacting with personal psychodynamics. Such an approach, therefore, clearly has much in common with the preceding approaches. That social variables are operative even before the individual is born is emphasized. Cultural patterns are mediated by the family; the individual is taught from birth. A value system communicated by verbal and behavioral means from parents and peers impinges on the individual. These values are introjected and help to determine his choice of a career.

Between birth and the age of five, factors such as role in the family, adult identifications, and parental relationships appear to be important as a foundation for later vocational decisions. Many psychodynamic data concerning early experiences are still missing. Knowledge of these experiences in the subcultural setting should provide meaningful information regarding the process of vocational development.

The typical scientist, to take a specific example, is a middle-class individual adhering to the Protestant ethic. In Kluckhohn's

[9] This is a statement of the view developed by Dr. McArthur in his memorandum and at the Panel Meeting.

terms (107a), he has *doing* rather than *being* values; is *future-* rather than *present*-oriented. He is ambitious, more interested in *facts* than in *values, inner-* rather than *outer*-directed, *thing*-oriented rather than *person*-oriented. In adolescence his growing maleness is threatening to him and his relationships, and he defends himself by becoming vitally interested in objects and ideas. He is, in brief, the product of cultural determinants and psychodynamic forces.

Summary concerning personality approaches

In closing this section on personality determinants of vocational development, it is appropriate to report the principles agreed on by the exponents[10] of this approach. These principles are:

1. Attitudes that characterize behavior in later years are laid down in very early years and by the beginning of the school period are already affecting behavior.

2. Apparent discontinuities in developmental trends are much more in evidence in adolescence than in previous or later periods.

3. We are all interested in selective perception. Particularly, we are interested in the "ruling out" process by means of which limitations and structure develop.

4. We are interested in the internalized social factors as well as the external social influences, and in possible conflict between them.

5. There is some correspondence between personality structure and occupational multipotentiality. A person may learn to fit his personality to the shape of a job by emphasizing some things and playing down others, also by changing certain characteristics of the job.

There is a narrower range of vocational possibilities centering around any interest or basic personality type than around any combination of abilities. In either case, there are limitations to the amount of modification possible. Change of behavior is another matter and is quite possible.

We reject the "common sense" fallacy that ability is all that counts, that a bright person can do anything with success and satisfaction. There is probably a narrower range of completely satisfactory vocational possibilities for a given personality or interest type than for a certain ability type.

6. Work has a different function in different personalities. In some, particularly at the professional levels, it is a salient thing, a focus of organization. In most adults it plays some part, but other self-percepts may be more central to the individual's identity.

7. The developmental process is irretraceable. Reintegrations leading

[10] The committee report was written by Drs. McArthur, Overstreet, Roe, Segal, Tiedeman, and Tyler at the Panel Meeting.

to different life plans are possible at any stage, but drastic changes become less possible with advancing age and increasing responsibilities.

Vocational development, then, is seen as one aspect of the general development of personality. It can be thought of as a series of decisions, each successive choice limited by decisions previously made. The choices made as life progresses are related to a pattern of needs that is laid down early in life, and are thus based on an emerging self-concept or sense of personal identity which results in selective perception of the environment. These choices may be made actively or passively, consciously or unconsciously, and they may be positive or negative, general or specific, deep or superficial.

Sociocultural determinants of occupational choice are internal as well as external, for they tend to become internalized and help determine the structure of the self-concept. The individual's personality needs and the structure of his ego-identity limit occupational multipotentiality by ruling out certain qualifying experiences. Work, for some persons, is a more important focus of a sense of identity than for others. Professional and scientific careers typically serve this function of providing a well-defined sense of identity.

TOWARD AN INTEGRATED APPROACH

These three basic orientations to the process of vocational development—trait-and-factor theory, social systems theory, and personality theory—are viewed not as mutually exclusive orientations, but rather as differences in emphasis. Thus one subdivision of the personality approach (the cultural–psychodynamic) appears to place equal emphasis on two of these orientations; and contemporary trait-and-factor theory deals with cultural as well as psychological factors, and emphasizes a developmental aproach. The remainder of this chapter will synthesize these three orientations in order to present a more fully integrated approach to vocational development theory. The integration focuses on the propositions, theories, and concepts common to the three emphases outlined above, and combined in Chart 2, pages 114-17.

VOCATIONAL DEVELOPMENT THEORY

Vocational development theory constitutes an approach to occupational choice which treats choice, not as an event occurring at a point in time and explainable by determinants which can be observed adequately at that same point in time, but rather as a process which takes place over a period of time, and which is best

Chart 2

AN INTEGRATED APPROACH TO THE PROCESS OF VOCATIONAL DEVELOPMENT

Developmental Stages	Vocational Development Process				
	Intra- and Inter-Personal Variables				
	Cultural Variables	Traits and Factors	Personality Development	Vocational Developmental Tasks	Vocational Developmental Opportunities
Preschool	Father's job income Parental attitudes values expectations residence social status	Sex Constitutional factors Intelligence Early interests Early aptitudes Physical appearance	Constitutional factors Early psychosexual development Position in family Parental handling and need satisfaction Identifications	To learn: Dependency Independence Social interaction Industriousness Goal setting Persistence	Opportunity to: React to parental handling and attitudes Explore environment Develop peer relations Develop authority relationships

ELEMENTARY SCHOOL	Urban–rural Religion Class affiliations School	Scholastic aptitude Emerging personality patterns Developing interests and attitudes Physical capacities	Parental relations Peer relations Authority relations Emerging identity or self-concept Success-failure reactions	Socialization Coping with school Dealing with family attitudes and values Developing own attitudes and values Passing school subjects	Opportunity to: Learn about world of work Develop attitudes toward school and school subjects Have after-school work experiences
HIGH SCHOOL	Family associates Family behavior Class values Peer values Teacher values	Special aptitudes and abilities Crystallization of interests Emergence of values	Heterosexual relationships Psychosexual development Adult role playing Clarification of self-concept Methods of need satisfaction	Choosing curriculum Developing study habits Making tentative educational-vocational choices Implementing self-concept	Opportunity for: Academic exploration Occupational exploration Social role exploration

Chart 2 (*Continued*)

Developmental Stages	Vocational Development Process				
	Intra- and Inter-Personal Variables				
	Cultural Variables	Traits and Factors	Personality Development	Vocational Developmental Tasks	Vocational Developmental Opportunities
Young Adulthood	Courtship patterns Marriage patterns Family finances Educational patterns Military service Labor market Occupational requirements	Crystallization of values, attitudes, and personality Motivation and drive at peak Intellectual and physical capacities at peak	Success–failure reactions Changes in identity or self-concept Changes in role Crystallization of self-concept	Evaluation of need gratifications: marriage college job Specification of goals Launching of career	Opportunity for: Choice of educational major, minor Further exploration in study and work Change of curriculum or occupation Return to student or beginner status in new field

MATURE ADULTHOOD	Family status Economic responsibilities Realities of the market place: war, depression, prosperity, technological change	Aptitudes on developmental plateau Gradual narrowing of interests	Role acceptance or rejection	Vocational establishment and advancement Resolution of conflicts	Opportunity for: Change of job or occupation Promotion In-service training

explained by a combination of determinants which themselves interact, are modified, and thus develop with time. One of the background papers (196) used in the present project contains a series of propositions and some relevant discussion which summarize this approach to career choice and occupational success. These propositions are quoted here, together with excerpts from supplementary material.

Proposition 1. Vocational development is an ongoing, continuous, generally irreversible process. Vocational preferences and competencies, and the situations in which people live and work, change with time and experience, making choice and adjustment a continuous process. This process may be described as a series of life stages, each of which tends to be characterized by certain types of behavior. These stages are, respectively, those of growth, exploration, establishment, maintenance, and decline, occuring regularly in the course of normal vocational development within our culture.

Proposition 2. Vocational development is an orderly, patterned, and predictable process. Individuals in a relatively homogeneous culture are expected to master much the same series of developmental tasks, some of which pertain to vocations. The aim of vocational development is eventual vocational adjustment, the criteria of which are basically the same for all individuals. . . .

Proposition 3. Vocational development is a dynamic process. It involves interaction between the behavioral repertoire and the developmental tasks that must be mastered, between existing responses and the new stimuli which are presented to the individual. It involves a compromise between or a synthesis of personal and social factors, self-concept and reality, newly learned responses and existing patterns of reacting. Thus, it may be described as a dynamic process involving interaction and integration of many psychological and social factors. . . .

Proposition 4. Self-concepts begin to form prior to adolescence, become clearer in adolescence, and are translated into occupational terms in adolescence. The underlying assumptions are that basic development of the self-concept occurs in childhood; that adolescence provides a period of exploratory experiences in which the concept of self is elaborated and clarified and that interests, values, and capacities are integrated and attain vocational meaning through the development and reality-testing of the self-concept.

Proposition 5. Reality factors (the reality of personal characteristics and the reality of society) play an increasingly important part in occupational choice with increasing age, from early adolescence to adulthood. As the individual matures and nears the threshold leading from the school to the world of work, he is confronted with the task of assuming vocational responsibilities which involve differing duties, values, and motivations. . . .

Proposition 6. Identification with a parent or parent substitute is related to the development of adequate roles, their consistent and harmonious interrelationship, and their interpretation in terms of vocational plans and eventualities. There is reason for believing that identification with a like-sexed role model in a society which places considerable emphasis upon proper sex differentiation is related to satisfactory work adjustments. Desiring to play a socially approved role which has an adequate occupational equivalent, and becoming established in an occupation in which one can play a desired role, are essential aspects of job satisfaction.

Basic to an adequate explanation of vocational behavior is the proposition that development through the life stages derives from the interaction of various influences. Biological, psychological, economic, and sociological factors combine to affect the individual's career pattern. Now one aspect of behavior, then another, is pre-eminent throughout the span of development. In each succeeding stage of life, the individual is faced with the necessity of coping with new and more complex stages of social demands, while adequately performing the tasks of earlier stages of development. . . . The accurate forecast of future vocational development rests upon the analysis of the individual at selected points in time and the examination of trends in an individual's career pattern over a period of time.

Proposition 7. The direction and rate of the vertical movement of an individual from one occupational level to another are related to his intelligence, parental socioeconomic level, status needs, values, interests, skill in interpersonal relationships, and the supply and demand conditions in the economy.

Proposition 8. The occupational field which the individual enters is related to his interests, values, and needs, the identifications he makes with parental or substitute role models, the community resources he uses, the level and quality of his educational background, and the occupational structure, trends, and attitudes of his community.

Proposition 9. Although each occupation requires a characteristic pattern of abilities, interests, and personality traits, there are tolerances wide enough to allow some variety of individuals in each occupation and some diversity of occupations for each individual. . . . One of the basic elements of the theory of vocational development is the concept of the occupational multipotentiality of the individual. . . . Both individual and occupational differences play an important part in determining the meaningfulness of a vocation to an individual.

Proposition 10. Work satisfactions and life satisfactions depend upon the extent to which the individual can find adequate outlets for his abilities, interests, values, and personality traits in his job. When the individual can find expression for his psychological characteristics in his workplace, he has the opportunity to develop feelings of self-realization, of belongingness, and of status. In short, he is enabled to take the kind of role to which he aspires.

Proposition 11. The degree of satisfaction the individual attains from his work is proportionate to the degree to which he has been able to implement his self-concept. It is assumed that vocational development is in part the development of a self-concept, and that the process of vocational adjustment is a process of implementing the self-concept.

A twelfth proposition was added to this list as a result of discussion by the Panel, reflecting recent work by Tyler (206) on sex differences, and by Darley and Hagenah (45) and Spencer (195) on socioeconomic differences. It follows:

Proposition 12. Work and occupation provide a focus for personality organization for most men and many women, although for some persons this focus is peripheral, incidental, or even nonexistent, and other foci such as social activities and the home are central. For persons who enter higher-level occupations the occupation itself tends to be the focus, but for those who enter many middle and lower-level occupations the work situation and the kinds of personal relationships which it permits or prescribes are more important. Here too there are sex differences, men being more career-oriented and women being person-oriented.

Chart 1 (page 106) depicted developmental stages, related sociocultural factors, and vocational developmental tasks and opportunities as conceived by a committee at the Advisory Panel Meeting. In order to reflect an integrated developmental approach, Chart 1 has been expanded in Chart 2 (pages 114-17) to include the trait-and-factor and personality orientations. The individual orientations are now the specific emphases of this developmental approach.

Chart 2 reflects the basic theme that vocational development is one phase of the general developmental process, subject to the same forces that impinge on the individual's general development. These forces are a combination of constitutional, environmental, and experiential factors or, more broadly, biological and social variables. Vocational development is seen as a developmental process in which an individual is confronted with decisions as to tasks and related opportunities, decisions which result from his own personality traits, the social systems with which he interacts, and the economic forces operative in his environment. It may help to develop this with an illustrative case.

An individual, John Doe, is born into a family. Constitutional factors have been operative prior to birth. These factors contribute to the determination of John's size, body build, other physical characteristics, intelligence, and special aptitudes, and, through his neural and endocrine make-up, influence personality development. His family identifies with a certain class as a result of the father's occupation and income, the family's place of residence, length of residence in the community, and perhaps religion and national origin. Social factors have fostered certain attitudes, interests, and values which are manifested in child-rearing practices. The climate of interpersonal relations of parents and child, the nature of need gratifications, important figures, and John's perceptions of these factors, contribute to the development of a personality structure which in turn contributes to the determination of future developmental patterns. As John matures, he is confronted with developmental tasks which have vocational implications. He learns appropriate dependency, moves toward self-direction and independence, deals with the socialization process, plays certain roles, makes certain identifications, and develops patterns of peer and authority relationships. He is concurrently afforded certain developmental opportunities: opportunities to learn of parental attitudes, values, and feelings, to relate to authority figures and to peers, and to make use of school experiences. The interrelationships of tasks and opportunities are clear to the observer if not to the individual.

Out of this pattern of general developmental tasks and opportunities and from the interaction of the forces mentioned, a sense of identity or self-concept develops. This is the initial stage of a formative process which extends over a period of many years. This process eventuates in a compromise or synthesis of these forces, tasks, and opportunities which in the vocational context is seen as a vocational preference and ultimately as an implemented career decision.

At each successive developmental level new traits or further development of earlier traits become operative, and different social and economic forces may become dominant. Factors shaping personality become less influential as the individual moves toward maturity. The nature of development in earlier stages helps to determine the characteristics of subsequent vocational developmental stages, leading ultimately to entry upon a career. Progressive exclusion and the relatively irretraceable character of this process clearly limit the range of such choice.

Chart 2 suggests that the classical trait emphasis becomes less appropriate in the study of vocational development in early and mature adulthood, as the variables normally stressed by the personality approach become prepotent. Social variables continue to exert themselves as strongly as ever at these stages. With the coming of adulthood, basic aptitudes and the personality structure have interacted with the social systems to form a life style and an emergent career pattern.

The seemingly neat compartmentalization of the variables in Chart 2 is an artifact of organization. A table with cells cannot well depict interaction between cells. Some of the variables are listed in all three emphases and appear as both tasks and opportunities, revealing the interactive nature of development. Obviously, vocational development is a much more complex and dynamic process of interactions than a chart can suggest. But it is clearly to an understanding of these interactions of traits and factors, social systems, and personality determinants that we should direct research in occupational choice, success, and satisfaction. Such research should, indeed, be research in vocational development.

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