The Psychology of the Scientist

A definite personality pattern, encompassing a wide range of traits, characterizes the creative scientist.

Anne Roe

Science is the creation of scientists, and every scientific advance bears somehow the mark of the man who made it. The artist exposes himself in his work; the scientist seems rather to hide in his, but he is there. Surely the historian of science must understand the man if he is fully to understand the progress of science, and he must have some comprehension of the science if he is to understand the men who make it.

The general *public* image of the scientist has not been and indeed is not now a flattering one, and at best it certainly is not an endearing one. Characterizations of scientists almost always emphasize the objectivity of their work and describe their cold, detached, impassive, unconcerned observation of phenomena which have no emotional meaning for them. This could hardly be further from the truth. The scientist as a person is a nonparticipating observer in only a very limited sense. He does not *interact* with what he is observing, but he does participate as a person. It is, perhaps, this fact—that the scientist does not expect, indeed does not want, the things that he is concerned with to be equally concerned with him—that has given others this impression of coldness, remoteness, and objectivity. (The social scientist is in a remarkably difficult position since the "objects with which he is concerned" are people, and both they and he may be more than a little ambivalent about this matter of interaction. But this is a special problem which I will by-pass here, noting only that in many ways the social scientist differs from the natural scientist in terms of personality and motivations.)

The truth of the matter is that the creative scientist, whatever his field, is very deeply involved emotionally and personally in his work, and that he himself is his own most essential tool. We must consider both the subjectivity of science and what kinds of people scientists are.

The Personal Factor

But first we must consider the processes of science. Suppose we take the scientist at the time when he has asked a question, or has set up a hypothesis which he wants to test. *He* must decide what observations to make. It is simply not possible to observe everything that goes on under a given set of conditions; he must choose what to observe, what measurements to make, how fine these measurements are to be, how to record them. These choices are never dictated entirely by the question or hypothesis (and anyway, that too bears his own particular stamp). One has only to consider how differently several of his colleagues would go about testing the same hypothesis to see that personal choice enters in here.

But this is just the beginning. Having decided what is to be observed, and having set up the techniques for observing, the scientist comes to the point of making the actual observations, and of recording these observations. All the complex apparatus of modern science is only a means of extending the range of man's sensory and perceptual capacities, and all the information derived through such extensions must eventually be reduced to some form in which man, with his biological limitations, can receive it. Here, too, in spite of all precautions and in spite of complete honesty, the personal factor enters in. The records of two observers will not dovetail exactly, even when they read figures from a dial. Errors may creep in, and the direction of the error is more likely than not to be associated with the observer's interest in how the findings come out. Perhaps the clearest evidence on this point comes from research on extrasensory perception. A scientist who is deeply committed to a hypothesis is well advised to have a neutral observer if the import of an observation is immediately apparent. Often, of course, such errors are minor, but they can be important, not only to the immediate problem but to society. I have wondered to what extent the disparity in figures on radioactive fallout may reflect such factors. Very few scientists, including psychologists, who have demonstrated selective perception as a laboratory exercise, take account of the phenomenon in their own work.

Once the observations are recorded, other questions are asked: When is the evidence sufficient to be conclusive, one way or the other? How important are discrepancies? What degree of generalization is permissible? Here, again, we may expect personally slanted answers. Taxonomy offers a very clear illustration of the effect of personality: One biologist may classify a given set of specimens into a few species, and another may classify them into many species. Whether the specimens are seen as representing a few or many groups depends largely on whether one looks for similarities or for differences, on whether one looks at the forest or the trees. A "lumper" may honestly find it impossible to understand how a "splitter" arrives at such an obviously incorrect solution, and vice versa. Such differences cannot be resolved by appeal to the "facts"—there are no facts which cannot be perceived in different ways. This is not to say that the facts are necessarily distorted. The problem of the criterion exists in all science, although some scientists are more aware of it than others.

The matter of personal commitment to a hypothesis is one that deserves more consideration than it usually receives. Any man who has gone through the emotional process of developing a

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new idea, of constructing a new hypothesis, is to some extent, and usually to a large extent, committed to that hypothesis in a very real sense. It is his baby. It is as much his creation as a painting is the personal creation of the painter. True, in the long run it stands or falls, is accepted or rejected, on its own merits, but its creator has a personal stake in it. The scientist has more at stake than the artist, for data which may support or invalidate his hypothesis are in the public domain in a sense in which art criticism never is. It may even be because of this that scientists customarily check their hypotheses as far as they can before they state them publicly. And, indeed, the experienced scientist continues to check, hoping that if errors are to be found, it will be he who finds them, so that he will have a chance to make revisions, or even to discard the hypothesis, should that prove necessary. He finds it less difficult to discard his hypothesis if, in his efforts at checking, he has been able to come up with another one.

The extent of personal commitment to a hypothesis is a prominent factor in the historical interplay between scientists. The degree of this commitment varies in an individual with different hypotheses, and varies between individuals. One very important factor here is the scientist's productivity. If he has many new ideas he will be less disturbed (and less defensive) if one fails to pan out. If he has very few ideas, an error is much harder to take, and there are many historical instances of errors which the author of the idea has never been able to see himself. I think many scientists are genuinely unaware of the extent, or even of the fact, of this personal involvement, and themselves accept the myth of impersonal objectivity. This is really very unfortunate. It is true that only a man who is passionately involved in his work is likely to make important contributions, but the committed man who knows he is committed and can come to terms with this fact has a good chance of getting beyond his commitment and of learning how to disassociate himself from his idea when this is necessary. There is little in the traditional education of scientists to prepare them for this necessity, and there are many who are still unaware of it. The extent of a scientist's personal involvement in a theory can now be a matter of grave public concern. Scientists who become advisers on political or other policy have an extraordinarily heavy responsibility for achieving some detachment from their own theories. How many of them realize this?

But once one hypothesis is found acceptable, this is not the end of it. One hypothesis inevitably leads to another; answering one question makes it possible to ask other, hopefully more precise ones. And so a new hypothesis or a new theory is offered. How is this new theory arrived at? This is one expression of the creative process, and it is a completely personal process. It is personal regardless of whether one or more individuals is involved, for in every advance made by a group, the person contributing at the moment has had to assimilate the contributions of the others and order them in his own personal way.

The Creative Process

There have been many millions of words written about the creative process, few of them very illuminating. The reason is not hard to find. The process is intimate and personal and characteristically takes place not at the level of full consciousness but at subconscious or preconscious levels. It has been inaccessible to study largely because we have not yet found any means for controlling it. Many effective scientists and artists have learned a few techniques which may reduce interference with it, but no one to my knowledge has discovered any means by which he can set it in motion at will.

It is probable that the fundamentals of the creative process are the same in all fields, but in those fields in which an advance in knowledge is sought, there is an additional requirement—or rather, one requirement receives particular emphasis. This is the need for a large store of knowledge and experience. The broader the scientist's experience and the more extensive his stock of knowledge, the greater the possibility of a real breakthrough.

The creative process involves a scanning or searching through stocks of stored memories. There seems to be a rather sharp limit to the possibility of very significant advance through voluntary, logical scanning of these stores. For one thing, they vary enormously in their accessibility to conscious recall and in the specificity of their connections, so that reliance upon conscious, orderly, logical thinking is not likely to produce many results at this stage, however essential such procedures become later in verification. This scanning is typically for patterns and complex associations rather than for isolated units. It may be, however, that a small unit acts as a sort of key to a pattern. What seems to happen, in creative efforts in science as well as in every other field, is that the individual enters a state in which logical thinking is submerged and in which thought is prelogical. Such thought is described as random largely because it typically tries seemingly illogical and distantly related materials, and it often makes major advances in just this way. It is not fully random, however, because it is goal-directed and because even in this preconscious work there is appropriate selection and rejection of available connections. This stage of the creative process is accompanied by generally confused or vague states of preoccupation of varying degrees of depth; it is well described as "stewing." It is this stage which apparently cannot be hurried or controlled.

Although termination of this stage (finding a solution, or "getting insight," as it is often called) quite frequently occurs in a moment of dispersed attention, it apparently does not help to induce a state of dispersed attention in the hope of provoking a quicker end to the process. It should be added that, while insights do frequently occur "in a flash," they need not do so, and that the process is the same whether or not the insight turns out to have validity.

To acquire the necessary store of knowledge requires long and difficult application, and as science advances, the amount of information to be assimilated becomes greater and greater, despite increasing generalization in the organizing of the data. Obviously, as more experience is stored and as the interconnections become better established and more numerous, the scanning becomes more effective. Such interconnections develop more and more readily as the process of acquiring experience takes on significance in the light of theory. This process requires not only the basic capacity to assimilate experiences but very strong motivation to persist in the effort. Strong motivation is also required if one is to continue with a search which may for a long time be unproductive. Motivation of this kind and strength derives from the needs and structure of the personality. Its sources are rarely obvious, although they can sometimes be traced. They do not necessarily derive from "neurotic problems," although they frequently do. It is no cause for dismay when they do. The ability of the human being to find in a personal problem motivation for a search for truth is one of the major accomplishments of the species.

If past experiences have brought about a compartmentalization of the storage areas, so that some portions are partially or wholly inaccessible, obviously the scientist is limited in his search. Compartmentalization of particular areas may result from personal experiences of a sort that lead to neurotic structures generally, or it may result from specific cultural restrictions, such as political or religious indoctrination. The extent to which such indoctrination will inhibit creative effort, however, depends upon how close the inaccessible areas are in content to the problems at issue. We have fairly conclusive evidence that political indoctrination need not interfere with inquiry into mathematical and physical science. Religious indoctrination can interfere strongly at any point, as history has documented very fully for us. The conclusion is no different from the basic principle of therapy: the more areas of experience there are accessible to conscious and preconscious thought, the better are the prospects for creativity.

Once an apparent answer to the scientist's question has been found, there is still a long process of pursuing and checking to be gone through. Not every man who can produce new ideas is also good at the business of checking them, and of course the reverse is also true. It is in the utilization of such personal differences as these that a "team approach" can make sense.

The Creative Scientist

This, then, is a brief review of what little we know of the process of creation. What do we know of the characteristics of scientists who can use this process effectively? Many lines of inquiry have demonstrated that the range of characteristics that are associated with creative productivity in a human being is very wide. These characteristics fall into almost all categories into which personal traits have been divided for purposes of study—abilities, interests, drives, temperament, and so on.

To limit our discussion to scientific productivity, it is clear to start with that there are great variations in the amount of curiosity possessed by different people. Curiosity appears to be a basic drive. I suspect it may vary consistently with sex, on either a biological or a cultural basis, but we have as yet no idea how to measure such drives. No one becomes a scientist without a better-than-average amount of curiosity, regardless of whether he was born with it, was brought up in a stimulating environment, or just did not have it severely inhibited.

Intelligence and creativity are not identical, but intelligence does play a role in scientific creativity—rather more than it may play in some other forms of creativity. In general, one may summarize by saying that the minimum intelligence required for creative production in science is considerably better than average, but that, given this, other variables contribute more to variance in performance. It must also be noted that special abilities (numerical, spatial, verbal, and so on) play somewhat different roles in different scientific fields, but that ability must in no case be below average. A cultural anthropologist, for example, has little need for great facility with numbers. An experimental physicist, on the other hand, does require facility with numbers, although he need not have great facility with words.

Personality Patterns

A number of studies have contributed to the picture of the personality patterns of productive scientists, and it is rather striking that quite different kinds of investigations have produced closely similar results. These can be briefly summarized in six different groups, as follows:

1) Truly creative scientists seek experience and action and are independent and self-sufficient with regard to perception, cognition, and behavior. These findings have been expressed in various studies in such terms as the following: they are more observant than others and value this quality; they are more independent with respect to cognition and value judgments; they have high dominance; they have high autonomy; they are Bohemian or radical; they are not subject to group standards and control; they are highly egocentric.

2) They have a preference for apparent but resolvable disorder and for an esthetic ordering of forms of experience. They have high tolerance for ambiguity, but they also like to put an end to it in their own way—and in their own time.

3) They have strong egos (whether this derives from or is responsible for their independence and their tolerance for ambiguity is a moot question). This ego strength permits them to regress to preconscious states with certainty that they will return from these states. They have less compulsive superegos than others. They are capable of disciplined management of means leading to significant experience. They have no feeling of guilt about the independence of thought and action mentioned above. They have strong control of their impulses.

4) Their interpersonal relations are generally of low intensity. They are reported to be ungregarious, not talkative (this does not apply to social scientists), and rather asocial. There is an apparent tendency to femininity in highly original men, and to masculinity in highly original women, but this may be a cultural interpretation of the generally increased sensitivity of the men and the intellectual capacity and interests of the women. They dislike interpersonal controversy in any form and are especially sensitive to interpersonal aggression.

5) They show much stronger preoccupation with things and ideas than with people. They dislike introversive and affect-associated preoccupations, except in connection with their own research.

6) They like to take the calculated risk, but it must involve nature, not people, and must not depend on simple luck.

Conclusions

How do these personality characteristics relate to the creative process in science as I have discussed it? An open attitude toward experience makes possible accumulation of experience with relatively little compartmentalization; independence of perception, cognition, and behavior permit greater than average reordering of this accumulated experience (the behavioral eccentricities so often noted are consistent with this). The strong liking for turning disorder into order carries such individuals through the searching period which their tolerance for ambiguity permits them to enter. The strong egos, as noted, permit regression to prelogical forms of thought without serious fear of failure to get back to logical ones. Preoccupation with things and ideas rather than with people is obviously characteristic of natural scientists, and even of some social scientists. This characteristic is not directly related to creativity, I think, but rather to the content of it.

I need not add that such statements as these are generalizations and that any individual case may be an exception. We may go farther, however, and generalize differences among men who follow different branches of science. That a man chooses to become a scientist and succeeds means that he has the temperament and personality as well as the ability and opportunity to do so. The branch of science he chooses, even the specific problems he chooses and the way he works on them, are intimately related to what he is and to his deepest needs. The more deeply engaged he is, the more profoundly is this true. To understand what he does, one must try to know what his work means to him. The chances are that he does not know or care to know. Indeed, he does not need to know. We do.

Science and the News

The School Bill: As Usual It Is in Trouble; Notes on Disarmament, Satellites and Radio Astronomy

It was generally reported last week, for the fourth time during the congressional session, that the school bill was dead, and the outlook for supporters of the bill was indeed even dimmer than usual. The remarkable event that triggered the latest batch of dismal reports was the decision of Senators Morse and Hill, chairmen respectively of the Senate subcommittee on education and of the full Senate Committee on Labor and Public Welfare, to sponsor a separate bill for the extension of school aid to the impacted areas.

(The impacted areas program provides grants in lieu of taxes to school districts containing substantial tax-free government property. Three out of four Congressmen and all Senators have impacted areas within their constituencies. The program expired in June, and one of the few things that can be said with absolute certainty about Congress is that it is not going to go home and face the voters without renewing aid for impacted areas.)

The principal hope for the immensely controversial general school bill was to tie it to the immensely popular extension of the impacted areas program; and the fact that two of the leading Democratic supporters of school aid were sponsoring a separate impacted areas bill suggested that the Democrats were throwing in the towel.

For all this, the latest reports of the demise of Kennedy's program, like the earlier ones, have been, at the least, premature. Welfare Secretary Ribicoff insists that the Administration is not giving up on the bill "until the last gavel falls," as he put it, and the last gavel, announcing the end of the congressional session, is not expected to fall for another month, during which time the Administration has considerable room for maneuvering.

What was, and remains, necessary for general school aid to be forced through the reluctant House was aggressive lobbying from the White House. This required a delay of a showdown on education until after the foreign aid bill had cleared Congress for the President's signature. The two Houses were expected to have passed their respective versions of the foreign aid bill this week, and a compromise version, worked out by a House-Senate conference, may be ready for a final vote next week. The way will then be clear for the President to move on education, although the White House has as yet made no public commitments on what, if anything, the President will do to break the log jam in the House of Representatives, where the whole Administration education program — school aid, National Defense Education Act extension, and aid to colleges —has been blocked in the Rules Committee.

The Morse-Hill move in the Senate last week was intended mainly to assure that, if the school bill failed this year, the aid to impacted areas would receive only a 1-year, rather than its usual 3-year, extension, thus making it possible next year to make another attempt at forcing through general aid to schools by tying it to extension of impacted areas aid. The Senate action had the incidental effect of warning the quite large bloc of fence-sitters in the House, who would prefer not to have to vote either way on the delicate issue of general aid, that if the House failed to face the issue this year, it would probably have to face it next year, an election year.

Meanwhile, responsible Administration aides have been hinting that the President might veto even a 1-year extension of impacted areas aid if that is all that gets through Congress. This, together with the accompanying message explaining why the bill was vetoed, would be the most dramatic possible way of focusing the nation's attention on the education program, and particularly on the failure of the House even to face the issue and vote the program up or down.

But this would be a politically drastic as well as a dramatic step, for the pressure to renew impacted areas aid is great enough to assure eventual passage, if necessary over the President's veto. If a veto, and the accompanying furor, forces the House to act on the broader education program, it will be a great victory for the Administration, but if it fails to force broader House action, and impacted areas aid only is pushed through, despite the veto, the Administration's defeat will only look so much worse.

What suggests that, barring a change of mood in the House, the President might take such a risk is that after calling school aid probably the most important piece of domestic legislation, and after the brave talk of his aides about fighting "until the last gavel falls," he is going to look a little silly if he simply takes a complete defeat lying down.