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How to Produce a Scientist

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ABSTRACT: This essay explores, on the basis of personal experiences and those of friends and colleagues, what causes young people to commit themselves to a career in scientific research, a question of interest to policy makers, educators and parents. I argue that an inclination and ability to do science is partly innate, but is not necessarily indicated by very high IQ. The home environment probably has more influence on the development of scientific interests and a scientific attitude than does formal schooling with its emphasis on rote learning and obedience. The most critical subjects required for development of scientific ability, beyond exposure to basic science, are English and mathematics, subjects that are weak in Thai schools. Among the qualities of successful scientists are an argumentative spirit and the ability to communicate, learn from others and cooperate in research. International cooperation and teamwork are vital to solving scientific problems facing the global community. I suggest that the "Science Olympics" competitions be altered to promote development of a cooperative spirit and international teamwork in science; at present, they reward only rote learning and individual effort, and are not structured to test true scientific potential or to reward any sort of scientific achievement.

Where do scientists come from? Of course, we know that mother storks bring them, just like all other babies. Can we say more than that? Probably not much. Most governments try to implement policies to increase the quality and numbers of scientists, and to promote recruitment into certain fields of science. But do we really know what makes young people go into science, and what makes people become good or great scientists? Are they predestined to become scientists at birth, or must they be nurtured to develop into scientists, or can bright people simply be persuaded to join the ranks of scientists, with rewards of jobs and money?

We don't know the answers to these questions very well, but based on my readings and personal experiences, I do have some opinions. In particular, I have some suggestions about what conditions will probably *not* nurture scientists. Modesty is called for, because many good minds have struggled with these questions. Also, the psychology of science is a relatively new field that is just beginning to pull together a body of observations and hypotheses regarding what constitutes scientific activity and what qualities, if any, distinguish scientists from other people[1].

Most scientists (myself included), though not all, were attracted to science, or "became scientists", at a young age—usually around 10–15 years. It seems likely that a predisposition was already present, and was "awakened" by some event or circumstances: a trip to the museum, an influential teacher, an experience with animals or plants nearby. In my own case, at age 10 our family moved to the countryside where I became excited by the birds, stream life, fossils, insects, etc., and I had plenty of time to wander about the woods alone and basically do nothing but look at things and collect them. I was also influenced by my older brother who also had biological interests and gave them respectability. Our parents were not scientists or even intellectuals, but they fortunately did nothing to discourage or change our interests. They tolerated and even encouraged the various hobbies that we took on at various times. The one thing we are most thankful for is that they did not try to tell us what to be in life.

Although I did well in science subjects, I was not greatly influenced by high school studies. I had some good teachers, but my biology teacher was not one of them. I distinctly remember him preaching to us one day "so you see, Darwin was wrong!" His ruddy face, with whitening hair in a crewcut, glared at the class as if to dare anyone to raise any question about it. Of course I didn't dare, even though I wondered at the time why Darwin was wrong—the teacher was the wrestling coach and known for his quick temper and lack of tolerance for dissenting argument. Perhaps I can credit the biology teacher with pricking my nascent interest in Darwin's theory, because I eventually developed into a biologist with a strong interest in evolutionary ecology. Apparently, I had been more influenced years before by my kindergarten teacher, who wrote on my report card "Warren is seldom interested unless the subject is science."

In general, I believe that developing young scientists are more influenced by the home environment than by secondary school work. There are several ways in which the home can provide an environment that nurtures scientific interests. One is to provide the child with the freedom and opportunities to pursue hobbies and interests. Many affluent homes do not provide such opportunities, and many parents lack the tolerant attitide that encourages free intellectual development. The house may be decorated with fancy objects that cannot be touched, or living room bars displaying colorful whiskey and liqueur bottles. Books and magazines to stimulate the mind are nowhere in evidence. There is no room the child can call his or her own to manage, and escape to. Of course, giving children complete scientific freedom in the home does involve some risks; most scientists have fond memories of the time their chemistry experiment blew up in the bedroom, the time the snake got loose in the house, and other scientific horrors.

The second way the home can nurture, or at least not quash, scientific potential is by not pressuring children to follow a certain occupation, or even to become scientists. Instead, whatever interests they may have should be encouraged. I know from examples from my friends, colleagues, and my own children that people will be most successful at doing what they like and what they decide to do themselves. I have seen people fail and become depressed because they did what their parents pressured them to do, and not what *they* wanted to do. Scientists, just like most people, cannot realize their potential unless they work on problems of their own interest, and suited to their own abilities.

Young scientists usually do not end up in the field of their original interest in science, as they have no way of knowing where their interests and opportunities will lead them. A young bug collector may end up as a molecular biologist. The young Richard Feynman started with ambitions in ornithology, then fancied doing molecular genetics, before settling in the field he was most talented in, physics (where he won the Nobel Prize).

I have dwelled on the ways in which the environment may influence young scientists, but what qualities do scientists have that distinguish them from other people? Can we recognize them or instill them in children? What is scientific genius? It is commonly thought to be some mysterious mental property or analytical ability. Most scientists now think there is no such mysterious ability, although it is easy to believe that some scientific or mathematical giants must have possessed something that all the rest of us mediocre scientists lack. Here is a short-list that most scientists would probably agree are important traits of incipient scientists.

1) A nonconformist mentality, or relative unconcern about what others think about oneself;

2) A doubting attitude, or the freedom of mind to question commonly accepted ideas and beliefs;

3) The ability to concentrate hard for a long time on a single project or problem;

4) An intense interest in nature or science, leading to hobbies, desire to explore and read more, etc.

These traits are often evident in children at a young age, but may not be recognized in shy children or in those whose interests or curiosity are suppressed. Scientific genius also does not require an exceptionally high intelligence, as measured by IQ tests, but only intelligence that is well above average. Extremely high IQ does not translate into exceptional creative or scientific ability. No test has ever been devised to measure scientific ability or potential. A case can be made that becoming a good scientist primarily requires, in addition to the qualities given above, hard work, stubborn persistence, a well-read and well-informed mind, and a certain amount of luck. These are not things that you can measure in brief tests.

Another common misconception about doing science is that it is a lonely activity, with scientists mostly working independently, in isolation from others. The truth is that no modern scientist will succeed by working in isolation. Science is a social activity like most other professions—scientists need to constantly discuss and test their ideas against others. Modern science involves much teamwork and collaboration; while good scientists try to think independently, they do not act independently. It also helps to have some social graces, and the ability to gain the trust of others. Scientists need to interact personally with others to get their ideas tested, get financial support and jobs, get manuscripts reviewed and published, have meetings, publish books, etc, etc.

One peculiar trait that good scientists all develop is the ability to have friendly arguments with colleagues. I remember in college seeing two scientists from different fields getting into a serious, vigorous argument lasting more than an hour during a lecture in front of students, who sat transfixed through it all. Later on they went out to drink beer together. This kind of behavior may perplex nonscientists, but it is part of doing science—at least in Western scientific culture.

The views I have presented about the development of scientists suggest that some children have predispositions to become scientists that may be partly innate, and require a particular type of social environment to grow to their potential. Moreover, it will not be easy to change the home, social, and school environments to nurture scientific ability. Clearly, family poverty may prevent or retard scientific development. Better teachers and better schools may help to promote science, but rote learning and the high value placed on obedience to authority that is traditional in Thailand and other Eastern cultures will tend to inhibit scientific learning.

Should we promote more, and more advanced, science courses in secondary schools? I do not think that this will necessarily create better scientists, because most of the scientific learning required is not imparted in classes—most is absorbed through self-learning outside of school or after graduation. Better teaching is more important than more courses. Moreover, the courses that are most needed are not more science courses, but those that improve language and math skills. The greatest deficiency in Thai schools is in the teaching of English. Students learn neither proper structure and grammar nor proper pronunciation. English has become the language of science, and without good speaking, reading and writing skills, a science graduate may become a good teacher, but will never become a successful researcher. Science has become completely globalized. Poor English reading and writing skills is the single-most serious problem with Thai science students at the university graduate level. All successful Thai scientists have fluency in English. This problem is rooted in the primary and secondary schools, where few teachers are sufficiently fluent themselves.

Of course, ability in mathematics has a direct relation to success in many scientific disciplines and the need to improve problem-solving ability in math has already received considerable attention by curriculum developers. But it is the language skills that need to be taught early in school as children are programmed to learn language most easily early in life.

The establishment of the international "Science Olympiad" is intended to promote science development in secondary school students and is supported by the Thai government. Thai students often perform well in these competitive quizzes and are rewarded. They become models for other students to emulate. Excelling in this type of competition requires rote learning and rapid recall of information. These are not the abilities, however, that demonstrate promise in science or promote success in science careers. In my opinion, the science Olympic games neither test for nor reward high potential to succeed in science—on the contrary, they contribute to a distorted impression of what science is. In addition, they create a nationalistic competitive atmosphere which is alien to science, where, on the contrary, international exchange of information and collaboration are vital to everyone's interests. Of course, scientists do compete with one another to attain priority for ideas and to achieve recognition, and in the more goal-directed fields this is a significant motivating factor. However, cooperation is, in general, more important than competition in scientific research.

Should we abandon these Olympiad science competitions? No, but perhaps we should design a scientific summit for students that promotes the true scientific spirit of mutual learning and international teamwork. Such cooperation will be needed to design solutions to pressing scientific, technological, environmental, or social problems. In the spirit of cooperation, I would like to suggest an alternative type of competition that would reward achievements closer to true scientific activity and collaboration.

The students would be divided up into small teams each combining different nationalities. Each team would be given a problem situation, for which they must design a program of investigation or research. They are given an introduction to the problem needing solution and set of background readings. Each team must summarize the relevant knowledge, outline the important issues, and design a program of investigation and research. They must also write a report and give an oral presentation of their solutions, which will be questioned and judged by their peers. The winning team will embody traits important in the modern scientific world: exchange of knowledge, analysis, persuasion, cooperation, and writing and speaking skills. It will also be a real international team, of students from North and South, East and West. There is no shortage of transnational and global problems which require the expertise of scientists of all stripes, and of all nations.

In fact, there are virtually no academic courses designed to train students in the arts of collaboration, leadership, analysis of real-world problems, or the ability to think globally. In the real world, scientists develop such skills on their own, on the job, after receiving a degree in a relatively narrow and reductionist field of science. Young scientists are told that science holds the solutions to the most serious problems facing society and the world, but they are not being given the tools to find and implement solutions to complex interdisciplinary problems.

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