What Are Excellent Scientists and Engineers Really Like?

The views of fifty Japanese researchers who became prominent after World War II－

Takayuki Nagata

Engineering Planning and Coordination Division, NEC Corporation

1. Introduction

An important method of researching engineering history is to interview scientists and engineers engaged in key technological developments and record their stories. In addition to details on the development process, one can hear about their experiences, such as getting a clue to a breakthrough from an experimental error or accident, being influenced by their boss, getting ideas from their associates or business partners, and having a warm relationship with their subordinates. Most such information would not be included in technical papers other than briefly, and often unclearly, in the acknowledgments. However, it is information that reveals a lot about the development process. In addition, it is only known by the person who was engaged in the work.

The Japan Research Industries Association (JRIA) organized an oral history study group in 1994. It has been conducting interviews the past five years, resulting in interview records on 50 people. The study group has two purposes. One is to keep and publish an accurate record of each main technology's development history. The other is to convey to high school students the wonder and excitement engineers experienced during the development process and the feeling of satisfaction that comes from success. This raises the level of interest among young students and leads many of them to choose science and engineering majors in college and then work for manufacturing companies.

Among other oral history interviews with the same purposes, fifty interviewees is an unprecedented number in Japan as far as the author knows. Another feature of this research is that the specialties of the interviewees cover a wide range.

The following standards were established for selecting the interviewees.

- ✓ A person who made a significant contribution to technological development after World War II.
- ✓ A person who has not been written about in books for the general public or taken up in the media and is thus not so famous among the general public, although is highly spoken of among professionals.
- ✓ A person whose work was not limited to a theory or concept, but was associated with at least one product that had an impact on society.

In addition to finding out about the interviewees' experiences, one can also learn about the interviewees' views on technology, their belief in and passion for new developments, their ideas on education and life, and so on. These are all interesting. Nevertheless, this paper places a greater emphasis on the interviewees' beliefs, gained through their experiences, about what constitutes an excellent scientist or engineer.

2. R&D Methodology

This section describes how the interviewees found a way to make progress in various situations. The descriptions are categorized as appropriately as possible in this section and in others.

1) Deep consideration and thorough pursuit

During R&D, engineers need to deepen and polish their thoughts by thinking about things over and over. It is a long and difficult journey, and sometimes seems to be endless. Still, engineers should try to enjoy their work. One day, a splendid idea may come in an instant like a "revelation from heaven" and result in a resolution. The following words of interviewees profoundly illustrate these points.

- ✓ "Trying to avoid thinking about problems is the worst thing you can do. In fact, overcoming a predicament with hard work gives an engineer real pleasure." (Said by Mr. Tadashi Matsudaira, who clarified what causes trains to have a zigzag motion)
- ✓ "You need to do your best in order to obtain the best solution. When I was struggling to find a solution, I thought about the problem day and night: on the train, while washing my face in the morning, and when taking a bath at night. This may have led me to lose track of what was going on in the world, including news about sports and entertainment. But it was well worth it." (Said by Mr. Masasuke Morita, who invented highly sensitive FM receiver systems and developed wideband digital microwave communication systems)
- ✓ "Be critical of your own ideas and attack them from every angle you can imagine. If they pass this test, a solution is at hand." (Said by Mr. Toshiyuki Kajiwara, who developed a new method of shape control for hot strip steel)
- ✓ "Raise your requirements, impose tough problems on yourself, and keep your goal in your sights at all times. Then, a great idea will come to you in a flash." (Said by Mr. Shoichiro Yoshida, who developed a stepper)

2) Breaking free from conventional thinking

It is very difficult for people to free themselves from fixed and preconceived ideas. Scientists and engineers are no exception. Very many scientists have wasted time wandering around in mental darkness. However, a pioneer has to propel himself forward with boldness. Even Max Planck was a reluctant revolutionist until he freed himself. All of the following interviewees either challenged the conventional thinking of the time or were unencumbered by it.

Mr. Shizuo Takashino, who spearheaded the development of the Sony Walkman, asked the section in charge of making motors to develop a very thin one. However, they said it was impossible to make such a motor, citing Flemming's Law. Thus, he decided to try to make one himself, and succeeded.

- ✓ "There are two kinds of taboos. One of them comes from God (for example, the impossibility of making a perpetual motion device). The other comes from the so-called professionals. The former cannot be challenged. As for the latter, we have to endeavor to squash them." (Said by Mr. Kajiwara)
- ✓ "I don't believe in conventional thinking in general. A really new idea is far removed from it and unpredictable in the beginning. But to arrive at that idea, we have to start in the comfortable world of conventional thinking." (Said by Mr. Izuo Hayashi, who developed the semiconductor laser)
- ✓ Mr. Yutaka Mochida, who led the Seikan Tunnel building project, said he was lucky not to have any predecessor in the world: he could not be poisoned by any fixed ideas.

3) With one’s own two hands

Of course, the knowledge gained from books and the information from technical papers and peers is important for R&D. However, we should accomplish what we set out to do with our own hard work. A development without this effort is normally much less significant. By experiencing our work with our own five senses and thinking for ourselves, we may find an overlooked idea and encounter an unexpected discovery. Moreover, we can have confidence in a result that is ours alone.

"Through the screening of bacteria with my handmade method, I was convinced of the importance of solvents and found that their distillation was indispensable. I did up to 300 analyses a week. Today, we can buy solvents easily. So they seem to be useful for raising the efficiency of research. But not making things with one's own two hands, whether they are solvents or something else, is a big loss." (Said by Mr. Nakao Ishida, who discovered various antibiotics)

Mr. Mochida walked from Tokyo to Osaka three or four times to decide the best route for the Bullet Train. He said, "We can't see the details in a comfortable journey on a horse's back and in the mood to enjoy flowers." When he was engaged in the construction of the Seikan Tunnel, he also went diving and investigated the bottom of the sea with a makeshift submarine, being unsatisfied with an unmanned probe.

"If you are apt to copy other people, you will end up a copycat. Then, you will get nothing despite your efforts. A person who tries to write a paper or render deeds as meritorious without doing important work by himself, will become spoiled in the process." (Said by Mr. Toju Hata, who discovered various antibiotics)

4) Go back to the starting point

When an engineer or scientist becomes stuck, he will become worried about how to go forward. However, in such a case, he should remain calm and go back to the starting point. Interviewees' experiences tell us that can be the easier way out.

"What are the essentials of microwave communications technology? While wondering about that, I realized how best to improve threshold power and, at the same time, made it compatible with an increase in the wide band gain." (Said by Mr. Morita)

"When someone is considering something, he often becomes confused and is not able to understand what he is doing. In such a case, first determine what parts of the problem you can't understand. Next, put those parts in their proper order. Then, you will see the scope of the situation and be able to think your way through to a solution." (Said by Mr. Mamoru Hosaka, who made the computer reservation system for Japanese National Railways)

During his stay at MIT, Mr. Hitoshi Narita, who developed the integrated duct propeller for large ships, was deeply impressed by the way his professor handled a situation when he came to a standstill. He went back to the beginning and thought about the problem with an open mind. From that time on, Mr. Narita has been doing the same thing.

"You should get into the habit of returning to the essence or the principle when you reach a dead-end. It seems like a detour, but is the easiest way out." (Said by Mr. Masakazu Hayashi, who developed a small turbocharger)

5) Learn from places and facts

The fundamentals of technologies are all in the realm of nature and can be found at development and production sites. We cannot develop good technologies without attaching great importance to these sites. Despite the fact that the sites are technological treasures, recently many engineers have not paid enough attention to them. A few of the interviewees warned these engineers. Today, we have made great progress in theories and computational technologies. However, there is a limit to human wisdom. It is impossible to predict all the things in nature, of course. Therefore, we have to learn from the phenomena that nature displays, and climb the ladder of knowledge step by step.

"Engineers don't make things by themselves nowadays. And they don't bother to go to the places where things are being made. Engineers need to know more about these places and the people working there. A new robot is made by learning from a highly experienced builder. We will not be

able to make new robots and other things if we stop having experts to seek out."
(Said by Mr. Yoshihiro Kyotani, who was the key to the linear motor car's development)

Mr. Masaharu Kunieda, who has developed a equipment for isolation of earthquake, had a trying experience. Despite completing his computer calculations, a freight car with a single axle trucks did not work. Through this failure, he learned that a single axle trucks is not suitable for a freight car. He says, in engineering, failures provide the most important information. He also cited the U.S.'s Tacoma Bridge falling down after a one degree of freedom torsion flutter, which was unthinkable based on the theory at that time. Thus, he emphasized the importance of learning the facts through actual exposure to the thing in question and its environment.

6) Don’t let opportunities slip away
In R&D, an unintentional or accidental event or failure during an experiment often gives a clue to a problem's solution. Many great discoveries in the history of science happened to come about accidentally. Nevertheless, superior insight and keen sensitivity cultivated through years of work are often necessary to convert accidental opportunities into reality.

Mr. Hideo Sasaki was looking for a way to adhere two pieces of metal to a large surface. He heard that a professor he knew was trying to develop an explosive technique for shaping but was having trouble because the material stuck to the mold. Mr. Sasaki thought he could apply this phenomenon to his work, tried it, and succeeded.

At one point when Mr. Tsuneo Akashi was engaged in the development of highly efficient ferrite, he was at a standstill, not being able to determine the right characteristics. He returned to his starting point and scrutinized all the data obtained. As a result, he figured out the relationship between good characteristics and specimens that were made on windy days. He supposed the following was true. Wind carried sand and it would get into the shack he used for experiments. It had been built soon after World War II and had many cracks in the walls. The sand would get into specimens and the main element of sand is SiO_2. Thus, Si should be the key. On this supposition, he doped Si in specimens and attained good characteristics with high reproducibility. This means the wind and shack enabled him to identify the impurity he had been looking for.

Mr. I. Hayashi was investigating the optical characteristics of AlAs grown on a GaAs wafer. He noticed a strong photoluminescence region. He applied this phenomenon to his research and succeeded in developing the double-hetero junction semiconductor laser. He said he happened to "stumble upon the photoluminescence region."

Mr. Tanba faced a deadlock in developing synthetic paper with a small specific gravity and white surface. One day, he forgot to add TiO_2 as a filler. In addition, by chance, the process temperature was lower than his specified setting. However, he was able to break the deadlock as a result of these two problems.

Mr. Hiroshi Ohama is the engineer who developed the electrolyzing technology for salt using an ion exchanging membrane. One of his big problems was creating a membrane with a hydrophilic property. After mistakenly reversing the electric polarity of a membrane, he discovered the solution by using his error as an opportunity.

7) Look at a problem from a different angle

You may find the solution to a problem when lost in a labyrinth of thought by looking at it from the opposite perspective.

● Mr. Shuichi Takada, who developed many heat pumps, was having trouble because of cracks in compressor blades. At first, he thought that greater strength would be obtained by tightly connecting the main blades and auxiliary ones and increasing the thickness of the blades. However, the situation did not develop as expected, and the cracks actually increased. Therefore, he adopted looser connections and thinner blades, which led to success.

8) Draw a picture

Two of the interviewees draw a picture before they begin their work. They believe in the effectiveness of pictures and utilize them well.

"I draw a picture of an object while visualizing what it will look like when complete. The basis of my work is pictures. If I can visualize what I aim to create, the actual work will be much easier." (Said by Mr. Takanobu Urata, who developed many image orthicons in the early days of television)

"I visualize the situation when I hear about a problem. When I can't do so and proceed while only armed with calculations, I will fail most of the time." (Said by Mr. Keizo Kikui, who developed an integration system so that multiple barges can be pushed by a large ship)

Mr. Urata is a descendant of artists. There were a few other interviewees who are themselves artists or are related to people of culture. Examples include an interviewee who travels 200 km to Mt. Hotaka every week to draw a picture of it, and one whose brother is a Cultural Medalist of Japan and himself a good painter. There thus seems to be some relationship between engineering work and pictures.

9) Laying a solid foundation

It is essential for any scientist or engineer to establish a strong foundation for his or her work. Two cases are below.

● Mr. Matsudaira was drafted into the army for a year during his early days as an engineer. He was forced to follow orders and was beaten if he did not. It was a life that had nothing to do with study, and he suffered from a hunger for knowledge. He returned to his laboratory upon his release from the army. When he was not working, he devoured all the books he could find, especially those related to vibration. He enjoyed studying until two or three a.m. and got up at half past six every day to restart his work-study cycle. He lived like this for half a year, which is when he sated his hunger for knowledge. At that point, he was confident that he could solve any problem on vibration.

Mr. Hosaka had enough time to study when he came back to the Ministry of Transport from the navy after World War II. His practical work in the navy and his subsequent studies gave him a solid foundation for accomplishing his many distinguished works.

3. Mental Attitude as a Scientist or Engineer

The following convey the readiness and mental attitude that interviewees emphasized as being necessary for any scientist or engineer.

1) Pay special attention to originality

Scientists and engineers should strive to attain their own originality. Seeking originality should be the basis of a researcher's thinking.

"You shouldn’t do experiments on dogs that are similar to ones already done by others using rats. Instead, you should seek out something no one has done or something that could lead to a new working hypothesis." (Said by Mr. Ichiro Chihata, who developed a production process for manmade L-amino acid)

"An engineer for a manufacturer should have the conviction that he will invent a highly revolutionary product and contribute to society with it, not being satisfied with mere incremental improvements." (Said by Mr. Morita)

Mr. Kajiwara said, "Your effort will lose meaning if you remain only a first-rate researcher and don’t become the best in the world." He also said, "Developing something that is highly valued by customers worldwide means you yourself truly love your product." These statements show that he has reached a special stage as an engineer.

2) Establish a new field

"A researcher should discover something and establish a new realm of science. He must not say 'I have done what I set out to do' until he has accomplished work at such a level." (Said by Mr. Yoshitaka Kobayashi, who developed an instantaneous analyzer for gasses very small in quantity)

3) It never hurts to try

Mr. Bun-ya Tadano, who is the Japanese pioneer of the electron microscope, emphasized the importance of the process over the ideal, citing the case of Ernst Ruska. When Ruska began research on the electron microscope, many researchers said it would never work because the specimen would be charred by the electron beam irradiation. However, he dared to try due to his belief that nothing could be said until it had actually been tried. As a result, his name was engraved in science history as the inventor of the electron microscope and he received a Nobel Prize. Mr. Tadano says that a man who has foresight that is so good that he stops thinking further after only a little studying is not suitable to be a researcher.

4) A can-do spirit

Mr. Sasaki always fought technological problems with resolve. He required the sales division to get as many difficult orders as possible for him to work on. He said that an engineer becomes toughened by striving to respond to customers' difficult (and sometimes unreasonable) demands. He expressed his principles through a tanka poem written by Banzan Kumazawa, a Confucian scholar in the Edo Era. One translation goes like this: "Let the ordeals come and come. I will send them away one by one. Life is limited. Ordeals need not be."

"It has never been tried by anyone. It is difficult. So let's take it on." (Said by Mr. Tanba)

"When facing adversity, I am not the least bit daunted. I rather enjoy it." (Said by Mr. Takao Momose, who developed a large drier that uses evacuation to freeze)

5) Researchers don’t weaken with age

Regarding the relation between research activities and aging, there are two general views. One is that they get worse after a certain age. The other is that they do not. The following words support the latter position.

Mr. Norikazu Sawazaki, the inventor of the helical scanning method for VCRs, said the change in researchers' ability with age is analogous to that of artists. Namely, the peak comes between the ages of seventy and eighty. He added that "By setting an age limit, Japanese companies force engineers to retire before their peak. It's so wasteful." Mr. Sawazaki himself is still developing new information storage methods at the age of eighty-five. Mr. Kajiwara had the same view as Mr. Sawazaki, although he said the peak is between sixty and seventy.

6) Do have a special ability

Mr. Kunieda preaches that acquiring a special ability is more important than being in a company, and stresses the importance of acquiring something that one can rely on in his life as an engineer. He has been constant in his devotion to vibration and rushes to wherever a vibration problem exists. Mr. Kunieda considers himself to be a "doctor of vibration problems."

7) Risk your life on research

The saying "risk your life on something" is often heard in various situations in Japan. Thus, it loses much of its terrible meaning through overuse. However, the following illustration shows how Mr. Kunieda thinks a researcher's mind should work.

According to him, Mississippi University in the U.S. requires students to make real airplanes. The students have to do the designs, strength calculations, wind tunnel experiments, and so on by themselves. When the airplane is complete, they have to get a license and fly in it. They truly put their lives at risk. Therefore, none of the required processes are neglected. Mr. Kunieda demands that engineers take responsibility for everything related to their work. He emphasizes that they should not say "As for further processes, we are not responsible from some point on."

4. How to foster the development of researchers

One of the most important roles of R&D managers is to nurture the growth of their researchers. Some people are capable enough to turn themselves into established researchers without any special help. However, most people derive a lot from the initial fostering.

Mr. Kunieda was sent to an aeronautical research institute due to student mobilization during World War II. He was given the job of finding out why heavy bombers' struts broke. By setting up differential equations and solving them, he was able to find the cause. His results were used to improve the bombers. Because he was only twenty-one or twenty-two, he was excited by the success and fascinated by the research. Mr. Kunieda says he was really lucky that at an early stage as a researcher, he was engaged in work to solve an urgent, real-life problem.

Mr. Tadano had an experience he will never forget. He was using his handmade cathode ray oscillograph to measure abnormal voltage induced in a power-transmission line by a thunderbolt. At the moment it struck, an electron beam swept across the fluorescent screen, drawing a blue wave form of the abnormal voltage. His heart beat fast and he quivered with excitement as he successfully measured the voltage. He felt the experiment was fascinating and worth devoting his life to. Mr. Tadano said, "I was lucky to be able to experience an experiment so exciting that it made me tremble." He believes that managers should have young researchers experience heart-pounding excitement as early on as possible.

● Mr. Ken-ichi Mori, who developed the first Japanese word processor, said, "Young researchers don't realize how creative they can be. Managers should give them confidence in this." He gives special training to newcomers to his laboratory so that they understand the pleasure that can be derived from thinking. After this training, they have confidence, knowing that if they try they can be creative.

When Mr. Sawazaki had his first paper printed in an IEEE Journal, a professor at the University of Tokyo and an authority on the subject matter said, "I have been following your way of thinking and theory development from early on. It's different from ours and very creative. Your last paper was very much so." Mr. Sawazaki was extremely delighted by the authority's praise, and it gave him enormous confidence.

5. Interviewee Comments

The following are not quite like those above. Still, they are interesting and worth presenting.

1) The merits and demerits of computers

Researchers have been depending on computers more and more in proportion to computer advances. Now, research without the aid of computers is almost unthinkable. Still, some interviewees pointed out the risk of depending on computers too much. They meant that computers should be used appropriately.

Mr. Takashino said: "In my youth, we actually attached resistors to sound equipment with our hands and then removed them the same way. We compared the sounds with our own ears and noticed slight differences. Nowadays, young researchers mostly depend on computer simulation."

Mr. Mochida said: "Developments in calculation methods and simulation techniques have enabled researchers to get lots of data. But it's impossible to pursue a principle using computers."

Mr. Matsudaira said: "In the old days, we derived a solution through troublesome calculations using our own hands as well as heads. Still, we got the essence of the phenomenon and were able to consider a better approach. Today, researchers can get a result easily by computer. And they are satisfied simply due to the fact that they can get a result. So, they have fewer opportunities to directly touch what they are working on and are unable to go beyond computer simulation."

Mr. Masahiro Shima, who developed a computer-controlled knitting machine, had his staff learn CAD during a recession when their work decreased. Still, he said, "Excessive reliance on computers causes the 'mental muscles' of researchers to weaken. We can't expect a fundamental invention from CAD. CAD is only a tool. Real thinking requires the brain."
Mr. M. Hayashi said: "Computers were very useful for analyzing the heat stress that couldn't be created in traditional experiments. We actually made experimental devices after trial manufacturing and experiments using computers. So our development work progressed very effectively." Mr. Fusayoshi Masuda, who developed a highly efficient moisture-absorbing polymer, said: "I don’t think computers can do creative work. But they are absolutely necessary to reduce researchers' boring and needless work."

2) Science and beauty coincide

Excellent scientific theories can be simple and beautiful. In addition, mechanical stability can exist together with the beauty of ancient architecture. Thus, some interviewees gave examples of science and beauty co-existing. Mr. Urata said, "Vacuum tubes need the beautiful curved line. It seems to me there is a close relationship between the theory and the feature." Mr. Kunieda, who likes to listen to and play classical music, said, "Technical papers should be as beautiful as music." When Mr. Hosaka was engaged in the computerization of car body design, he had the chance to work with a designer. Mr. Hosaka was unable to understand the meaning of the lines that the designer drew using his sense of aesthetics. Still, it turned out that the lines Mr. Hosaka later got through scientific analysis were almost the same as those of the designer.

6. Conclusion

Through these interviews, we learned a lot about what 50 outstanding scientists and engineers in post-World War II Japan believe is important for achieving excellence. We learned many other things as well, for example, the reasons they were so ardent and full of vitality, and interesting anecdotes related to developments. When the chance comes, the author hopes to present these matters in detail.