Restoration of engineering and *Synthesiology*

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The Engineering Academy of Japan with its abundant knowledge and experience discusses and issues statements on a variety of topics in engineering. The "Study Group for the Restoration of Engineering" reconsiders the meaning of engineering in the modern world from different perspectives. Since the significance of engineering is closely related to the mission of *Synthesiology*, Akira Ono, Chairman of the Editorial Board of *Synthesiology* interviewed Dr. Kotobu Nagai, a member of the study group, to hear his thoughts on the "restoration of engineering," and discussed its relationship to *Synthesiology*.

***Synthesiology* Editorial Board**

Kotobu Nagai: EAJ Study Group for Restoration of Engineering, National Institute for Materials Science
Akira Ono: Editor-in-Chief, *Synthesiology* , AIST

Why a study group for "restoration" of engineering?

(Ono)
I think the *Kogaku No Kokufuku Kenkyukai* or the "Study Group for Restoration of Engineering" of the Engineering Academy of Japan shares a similar perspective to *Synthesiology*. What is your intention of not using the homonym *kokufuku*, which is a word meaning "to overcome a difficult situation," and instead using *kokufuku* meaning "to restore the original state of wholeness"?

(Nagai)
Recently, there has been talk of a "drift away from science" and "farewell to engineering faculty." Even though engineering is a very important field, young people are turning away from it, and I've always felt that that is a worrying trend. Another point is that the members of EAJ are Japan's foremost engineers, but they are growing old. All the traditional academic societies of Japan are unable to increase their membership and are aging. It is with a sense of urgency that "something has to be done" that we used the word *kokufuku* meaning succumbing to disease and then regaining health, rather than *kokufuku* meaning to overcome. It is in the sense that we must return to a wholesome state, that we are intending to start a movement that may promote the value of engineering in such a way that it is appreciated properly by young people.

Researchers must reconsider the essence of innovation

(Ono)
Today, the interest in innovation is high globally, and I think "restoration of engineering" is related to innovation. What do you think is innovation to Japanese industry, society, and people?

(Nagai)
While technological breakthroughs are important, in Japan, I think there is a tendency to consider certain breakthroughs as synonyms for innovations.

The people of industry say that the available guiding principles or scientific principles are approaching their limit, and will reach their limits by 2020 to 2030. They know that what they have in hand now has only limited capability to respond to oncoming global changes and new demands and they are seeking ways to stir up real innovation.

Dr. Ono (left) and Dr. Nagai (right)

The rising prices of resources and energy such as that which occurred last year seems to have moved into the background because of the American economic troubles. For society, however, there is an increasing realization that these trends will not change. The way to overcome the social limitations of resources, energy, and the global environment and at the same time create a society where people can live comfortably and securely are the root of the innovations demanded by society.

The fourth phase of the Science and Technology Basic Plan is now starting. The expectations for science and technology have increased and society is making large investments. The technology policy makers are strongly voicing the opinion that the effect of this investment must be made visible to ensure such investments are used to promote industry and the corresponding benefits are returned to the society. This, of course, is a just demand. Yet going back to the level of researchers, they cannot respond to such a demand as long as they believe a "breakthrough is innovation." The researchers may feel, "I worked so hard to discover or invent this wonderful thing," but may be unable to fill the gap between the contemporary capabilities of Japanese industry and the state of the art discoveries; society is incapable of utilizing the results. From another perspective, there may be other companies in the world that possess the ability and mindset to use such state-of-the-art discoveries, and the results obtained in Japan may be utilized in other countries, and that would be a problem.

I think the word "innovation" is used to emphasize the fact that we must reconsider how and where a boost can be given to society, going back all the way to the level of individual researchers in order to use the taxpayer's money for the benefit of Japan.

(Ono)
This point is something that I can sympathize with from the standpoint as an editor of *Synthesiology*. I think "going back all the way to the level of individual researchers" is very important.

(Nagai)
The "innovations" talked about by industry and society, and in technological policymaking are different, but there is shared expectation that various breakthroughs will come together into a new direction and give rise to a paradigm shift. For Japan, how do we obtain the necessary resources and energy? We need direction so that we are welcomed and do not become a burden to the world, and we must have firm sense of direction. In that sense, engineering must be at the vanguard, but it is in this sense that it is regretful that we must talk about the "drift away from science" and the "farewell to engineering faculties."

Let us define "engineering" as "the science of problem solving"

(Ono)
Regarding Japanese engineering, we had excellent technology but it was lost somewhere along the way. When you say "restoration of engineering," what do you think is engineering? Do you think there is a science unique to *kogaku* (engineering) that is neither technology nor science?

(Nagai)
There is a four-character word *ka gaku gi jutsu*, which is translated "science and technology," and it is quite difficult to define. I think we must consider *kagaku* (science) and *gijutsu* (technology) separately to seek definitions that are valid today, and then redefine the *kagaku gijutsu*. Some people say "Japanese ambiguity" is good, but ambiguous guiding principles may lead us to failure.

(Ono)
First, we must define the words clearly.

(Nagai)
Kogaku is plainly "engineering" in English. However, some people say *kogaku* is "science and technology and engineering" or "the science of engineering." Although I understand these points of view, I believe that "*kogaku* is the science of problem solving."

Dr. Kotobu Nagai

Dr. Akira Ono

However, I am beginning to think that the definition of *kogaku* is beginning to waver in Japan. This may upset some people, but engineering faculties in Japan are approaching something closer to science. There have been comments from people in industry that the meaning of the word *kogaku* has been stretched, and *kogaku* is departing from engineering faculties that are supposed to be the final stronghold of *kogaku*. Recently, many reports blatantly state, "Engineering faculties are no longer pursuing proper engineering but are sub-science faculties or science-faculty-like engineering faculties." Students who were planning to get into engineering for problem solving decide to go into other areas of science, medicine, or economics. I believe that this happens because engineering faculties are loosing their original stance. The concept of engineering faculty was a derivative from the science faculty, and in fact, Japan was the first country that created a faculty of engineering.

An age where "science" must evolve alongside "technology"

(Ono)
You say that there was an original Japanese *kogaku*. To seek the original definition of *kogaku* is the starting point of the restoration of engineering.

It is said that science and technology are beginning to fuse, while others state, they are mutually exclusive and are evolving separately. What are your thoughts on fusion and exclusivity?

(Nagai)
The history of Asian science and the history of Asian technology are not studied extensively. While the history of Western technology is not studied heavily in the West, the history of Western science has been extremely well studied. Dr. Yoichiro Murakami, Professor Emeritus of the University of Tokyo, provided a comprehensive explanation: "In the West, there are two things that God created. One is the Bible, and the other is nature. These are the divine revelations. Western science was born because the purpose of scholarship was to clarify divine revelation."

(Ono)
One of the origins of Western science was to realize or to seek the divine world according to Christianity. It was closely linked to theology.

(Nagai)
Yes. On the continent, scientists were supported by royalty, while engineers had relatively low status. In contrast, in England, scientists were considered arrogant and useless, and engineers and craftsmen were favored. In the Renaissance, the encyclopedia was created since "God did not create nature in a systematic manner, but created it randomly and abundantly. One can approach God if one understands all randomly created things." It was around this time that the relationship with tools became very apparent in the history of science like, for example, Galileo Galilei needing a telescope to perform his studies or to carry out experiments rather than just thinking.

According to Dr. Murakami, the reason for change in Western science is because the Westerners fought the Muslims. They studied and assimilated the things left behind by the Muslims, and they realized that they failed to properly assimilate Socrates and the Hellenistic culture. A great turning point occurred through their restudying of foreign cultures. This is much like the origin of *Synthesiology*. Some of the theologians decided that things did not have to be systematic, and came up with the encyclopedia style.

(Ono)
The gathering of facts is foremost in importance.

(Nagai)
Yes. At around the time of the Industrial Revolution, science and technology ran into each other head on. In technology, making "things" was the objective. Whether it was the printing press, explosives, or a compass—there are theories that the water mill was created in the Orient—, they only had to be constructed and made practical. Principles were unnecessary. I think this is the wonderful part of technology.

Science, on the other hand, is a pursuit of profound truth created by God, and in a sense it does not require results. I think this is wonderful too, and I don't think either should be regulated in any way. I do think there is an attempt to change from the encyclopedia style.

First, how do we describe the current age? One is that it has become flat, as exemplified by the word "mass globalization." The world has become very small through the development of traffic and communication. Information can diffuse throughout the world in an instant. It is a new age in this respect.

Around 2050, the world population will be 1.5 times its current value, and about twice the amount of resources and energy will become necessary. The emission of carbon dioxide will at least double. The remaining resources and energy will shrink. After the world population reaches the peak in 2050, the average lifespan will increase. The 21st century is an era when people will age on a global scale.

On the other hand, the speed of development of science and technology will accelerate even more.

(Ono)
Does that mean that we must accelerate the development of science and technology?

Technology backed by science is sought by industry

(Nagai)
No, I mean that they will accelerate. Looking at the trend of the number of research papers published, the number has increased dramatically with the participation of China and India. As more people participate, new information comes out worldwide at a greater speed. While the probability of serendipity does not change, according to the principle of "more shots more hits," new concepts will emerge more quickly than before. In this age, anyone who can make use of novelty will win. While there will be chances for scientists and engineers to make big profits, we may end up with terrible consequences for society and humankind. In the sense that science and technology will have to play their significant role with care, a totally new age may arrive.

(Ono)
Does that mean an age where technology and science come closer?

(Nagai)
The speed at which new scientific knowledge and technologies are born and the speed at which they are learned will continue to accelerate. Therefore, unless the technology is excellent and is backed by science from the beginning, it will weaken when adopted by industry. Technology must be supported by science, so I think science and technology must become closer. However, from the standpoint of science, it doesn't really have to approach technology. We do not want to choke science, and I understand very well when Dr. Masatoshi Koshiba says that he'd want to be doing whatever he likes even after several thousand years.

Japanese science, technology, and engineering

(Ono)
I would like to ask about Japanese science, technology, and engineering education. There was a time when Japanese technology was called "copycat technology," but now Japan is considered to be one of the most successful countries in technological innovation.

(Nagai)
Japanese technology is considered to be extremely advanced by other countries, and I think there are three important aspects to consider. Military technology progress is overwhelmingly dominated by the United States, but not in Japan. So-called civilian technology is regarded hotly by competitors both in Japan and around the world, and as long as Japan and the Japanese possess the capability to handle them, we will continue to create overwhelmingly wonderful things.

(Ono)
I think the fact that the Japanese users are highly quality conscious makes a difference.

(Nagai)
Yes. Second, there is a keen awareness that Japanese products are to be sold around the world. Three, and this is often disregarded, but I speak from the perspective of a metal materials researcher: there is no other country that is so densely populated and experiences serious earthquake damage like Japan, and therefore, the materials used here are the toughest in the world.

As there are several factors that make Japanese technology strong, it has been required to be strong and robust against accidents or disasters, which, in turn, established the Japan brand, and I expect this will continue into the future.

(Ono)
Technologies have developed in their respective regions of the world and have their own logic. In Japan, there is the background of earthquakes, the societal situation of low birth rate and aging, and issues regarding energy. These factors provide mechanisms that nurture the growth of technology, and with a proper mindset, it has worked very well so far.

While it has excellent technology, how about Japanese science?

(Nagai)
It is quite difficult to respond in a simple way to the question, "why do we do science?" In terms of matching up to first-class science in the world overall, Japan does not hold a good position. At this point, we are number one in the field of materials, but China is close behind us.

We have entered an age of mass globalization, and all information diffuses widely. However, when seeking optimal solution, localization becomes very important. We cannot solve a problem if we are simply copying other countries. This is true for science. However if we say, "Don't copy other countries," people won't copy at all, but we must copy certain things. There must be diversity. I think if we look back at the excellence of Japanese technology, we can find its origins in various new topics of research.

(Ono)
For Japanese technology, I can describe characteristics that make it excellent, but I cannot find any for science. At this point, the only good point I can see is "we don't copy," and that is a harsh reality.

There was a time when Japanese engineering shined.

(Nagai)
In our study group, we analyzed what were the greatest achievements in Japanese engineering after WWII. We can say with confidence that it is the factory system. The supply chain, and everything from control, management, and operation technology in total is absolutely wonderful. Seen from the world perspective, Japanese plant technology is the textbook of textbooks.

(Ono)
Do you mean it's not only about introducing industrial robots?

(Nagai)
On the other side, there is no hesitation in introducing industrial robots, and there has been the wisdom and tradition to do so. While the layoff of laborers by introducing industrial robots must be considered a separate issue, technological innovation can be extremely severe and inevitably results in sacrifices. I don't think technological innovation will make all people happy, and there will always be people who suffer loss. Wisdom is required to see the correct direction while weighing the welfare of society in total.

Engineering education is not studying "science" but studying "what is science"

(Ono)
Regarding Japanese engineering education, you mentioned today we are saying "farewell to engineering faculty," and that's unfortunate. What made the engineering faculty shine?

(Nagai)
I said Japan was the first country in the world to create an engineering faculty. At the beginning of the Meiji Period, the Ministry of Engineering created the Imperial College of Engineering, and the world's first engineering faculty was established. Henry Dyer, a Scotsman, was invited to Japan to design the education plan. At the time, the ministries had college-like institutions. It was like the Ministry of Economy, Trade and Industry running a university.

I read Henry Dyer's "Valedictory Address to the Students" at the first graduation ceremony, available at the library of the Tokyo Institute of Technology. It was written: "On the continent, the status of science is high and technology is placed below it, and good results could not be obtained. In England, technology is given an extremely high status, but it is unrelated to science, and although the results are good, they engage in trial-and-error indefinitely so development cost is high. I was invited to Japan because I wanted to design new education paradigm by taking the best of both." To carry out a new type of university education for the transmission of skills and for teaching world's most advanced science, the practicum and lectures were very well combined. Of the six years in school, the 5th and 6th year students went to the site of the Ministry of Engineering to do hands-on work, and were required to write a graduation thesis.

The address includes points such as: the university must properly manage the library and resource rooms so the students can go and study the best works of their forefathers; an academic society must be established; or one must study foreign languages to directly learn state-of-the-art knowledge. These are common sense today. It is also written that one must actively study literature and religion. To think why one is studying cannot be done without such knowledge. He goes on in the lecture that "when you start to work and meet people from other countries, whether you can name one literary work of that country will affect how you will be received."

(Ono)
I hear that story now, but I see it started back then.

(Nagai)
He talked of ideals, but I think the ideals ring true to this day. As criticism of the continent, he already said, "In engineering, one is less able to make anything good when he is packed with more knowledge. We must have the students study 'what is science' and there is no need of studying 'science.'" I understand this thoroughly.

What "engineering" can do in the 21st century, the age of collaboration and competition

(Ono)
Did Japanese engineering shine for the second time in "monozukuri" or "manufacturing" centering on industrial technology after the WWII?

(Nagai)
I think it is "monozukuri" or "manufacturing" itself. When it is called "transmission of skills," it invokes an extremely personal image, and I don't find it useful. However, if a skill is transmitted without the spirit of manufacturing, people may say, "We don't want it." This is written in "To Those Aspiring to Be Scientists" used by the National Academy of Engineering (USA), and has been mentioned by Henry Dyer, but in my own words, I think human beings are the only animals that can have dreams or have curiosity in that they wish they had some thing, and can use the materials in the environment to create and realize those dreams. Curiosity is born when one comes across different things or different thinking styles that he/she never imagined existed. In my generation, my curiosity was raised by seeing things that did not exist in the real world in the manga "Atom Boy." To come into contact with different things, and to actually try them out— if it works, you may be convinced that you are

a genius, but that is important. Then, you must go out to the world and challenge established ideas. I think that is what "the age of collaboration and competition" means.

In an age where a problem cannot be solved with only one idea, to remove the walls and to share knowledge and ability are something that only humans can do. Of course, the basics are important. While merely packing in knowledge won't work, education is important.

(Ono)
What you said is certainly the spirit of *Synthesiology*. I think this will lead to the third success of engineering in Japan.

(Nagai)
From the standpoint of *Synthesiology*, I think it is necessary to build such mechanisms and activities at all levels and in all places. The key point is education in high school and above. It is necessary to create an environment where different ideas can compete. This means to nurture "dreams" and "curiosity."

Design is the essential human ability and the origin of engineering

(Ono)
Is this related to "design is the essential human ability"?

(Nagai)
I mentioned it for that purpose. Taking it to an extreme, I believe we can go ahead and create a new engineering faculty by combining the current faculties of economics, law, and engineering of Japan.

(Ono)
The general term for all of that will be design.

In our discussion today, your contrast of science and technology was very interesting. While Western science has its origins in the clear objective of seeking God's design, there is no clear explanation of why science exists in Japan, and it's not going to endure by just being interesting. However, Japanese engineering had shone bright twice so far, and it is trying for its third glory, and I see that it is in good standing. This must be stated clearly, and the flag must be flown visibly. This is perhaps the same as strategy making.

(Nagai)
I think strategy making is important. It will be an issue for the third shining age of engineering.

(Ono)
Thank you very much for a valuable discussion.

(This interview was conducted at the National Institute for Materials Science in Tsukuba on August 19, 2009.)

Profile of Dr. Kotobu Nagai

Completed the masters program at the Faculty of Engineering, The University of Tokyo in 1977. After working as assistant at the Faculty of Engineering, UT, transferred to the National Research Institute of Metals (which became the National Institute for Material Science in 2001) in 1981. Worked as the head of Mechanical Engineering Lab, head of the Steel Research Center among others. Currently the Area Coordinator in charge of the Environment and Energy Materials. Doctor of Engineering (The University of Tokyo 1981). Member of Science Council of Japan. Specialty is metal material science (basic themes are clarification of the relationship between microscopic structure and mechanical properties; and compatible design of low environment load and high performance).