Synthesiology Workshop

Methodology of technology integration toward establishing an open innovation hub

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The Synthesiology Workshop was held in October 2010 as part of the lecture series for the "AIST Open Lab" organized by the National Institute of Advanced Industrial Science and Technology (AIST). This is a report of this workshop.
In this workshop, an attempt was made to categorize the academic papers published in *Synthesiology* into various types of synthetic research. Ways to promote innovation were discussed with the industrial researchers who have been engaging in synthetic R&D and have produced successful results.

***Synthesiology* Editorial Board**

[Opening Address]

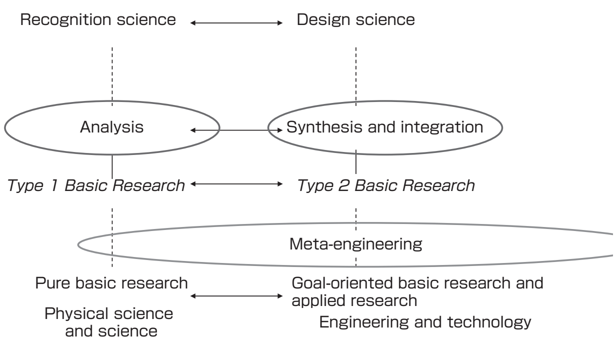
Akira Ono (Editor-in-Chief, *Synthesiology*, AIST)

The international competition for innovation is becoming fierce. While there are heated discussions about "open innovation" and "collaboration among industry, academia, and government" here in Japan, I think it is important to understand the situation as a whole, to engage in discussions on what are the mindset, objectives, and shared area among researchers and engineers, in order for the academia such as universities, public research institutes like AIST, and the industries to understand each other and deepen collaboration despite our differences.

Overlooking the method of research in science and technology, the traditional science started in 17th century Europe, and has been successful by employing reductionism. The success continues to the present, but many people are beginning to realize that reductionism alone will not solve complex problems of environment, energy, and safety. There have been several proposals for new scientific methodologies that do not rely on reductionism. For example, if we consider recognition science to be the traditional science, why don't we have design science as a new science? When handling complex problems, don't we need approaches of synthesis and integration where we are not grounded in a single technological field? At AIST, we have the contrast of *Type 1 Basic Research* versus *Type 2 Basic Research*. There are also contrasts of pure basic research versus goal-oriented basic research or applied research, and also science versus engineering, as well as science versus technology.

Compared to the traditional scientific methodology, we paid very little attention to the methodologies and approaches for the new science, even though we are practicing such research on a daily basis. Or, each scientist may have an accumulation of know-how, but these are not shared as assets

Research method for science and technology



of society and cannot be handed down to others. Those are our understanding of the issue. I think the objective of *Synthesiology* will serve as a point of discussion.

Today, under the title “Methodology of technological integration for the open innovation”, we invited several people with broad views and rich experiences. I hope we have a deep discussion on the new scientific methodology.

[Presentation]
Categorization of synthetic research for the creation of innovation

Naoto Kobayashi (Senior Executive Editor, *Synthesiology*; Waseda University; former AIST member)

Synthesiology is a journal for papers that emphasize the objective and scenario of the social technology that leads a research result to product realization and its social diffusion. If these papers could promote the practice of *Full Research* and accelerate innovations, *Synthesiology* will play a major role as an academic journal. While the creation of innovation is not easy, it would be beneficial if we can get a glimpse of the integration methodology that may lead to innovation. Therefore, the Synthetic Methodology Working Group of the *Synthesiology* Editorial Board has reviewed 50 papers among the 60 papers published from Vol. 1 No. 1 to Vol. 3 No. 2. The papers were comprised of: 8 papers in environment and energy field; 9 in life science (biotechnology) field; 6 in life science (human technology) field; 10 in information technology and electronics field, and nanotechnology, materials and manufacturing field; 12 in metrology and measurement science field; and 5 in geological survey and applied field geosciences field. I have previously proposed the (1) “Aufheben” type (two opposing topics are integrated to create a new concept), the (2) Breakthrough type (marginal technology elements are combined with major essential technology element to develop integrated technology), and the (3) Strategic selection type (technology elements are strategically selected and synthesized). These concepts were used as examples for the basic types of synthesis method.

Overall, the papers of *Synthesiology* were found to be interdisciplinary, but we have also discerned characteristics for each field. The (1) environment and energy field mainly involved the “strategic selective + breakthrough types”, where the topics are selected strategically as the clear social demands are broken down, a main technology is generated from the key elemental technologies, breakthrough occurs with the combination of the main and marginal technologies, and an integrated technology is born.

The characteristic methodology for the (2) life science (biotechnology) field is the spiral development. For example, in bioinformatics, after a core technology is synthesized, this leads to the hop-step-jump phases of the next development, and this Full Research loops up to the “hop” of the next stage. The biotech industries have higher uncertainties than other fields, where one may not know whether a product is usable unless it is realized as a product, and it is important to bring the product to realization however small. The spiral manner in which the processes of *Type 1 Basic Research*, *Type 2 Basic Research*, and *Product Realization Research* spiral upward is the characteristic of the field. Moreover, in the (3) life science (human life) field, as represented by the paper on the development of eyeglass frame to match an individual, its characteristic is to create a system for providing a product based on customer satisfaction by integrating the technology elements, categorizing the core technologies, and by seeking new findings.

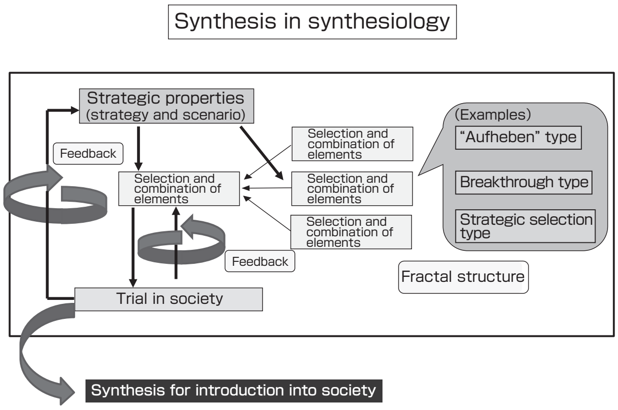
In the (4) information technology and electronics field, the creation of nonvolatile electronics using the spintronics technology was very typical. It could be called a tandem breakthrough type, where there are two consecutive breakthrough technologies including the development of the new material and device and the development of the mass production technology that is crucial for practical use and product realization. In the (5) nanotechnology, materials, and manufacturing field, the mass synthesis of organic nanotube is one of the good examples. While this is a seed-driven breakthrough type, the characteristic is that the mass production was attained by extremely detailed molecular design and the integrated technology, and the practical use has been sought by pioneering the use of the product jointly with various companies.

In the (6) metrology and measurement science field, there is the mission of establishing the national standard and providing traceability to the International System of Units (SI), guaranteeing the international equivalency of the standard using a measurement method recognized internationally, and building a traceability system that reaches the far corners of society through standard provision. The technological development can be called the “strategic selection type S (standard)”. Its characteristics are that the goal is clear, and the technology elements necessary for its achievement are selected and synthesized. Finally, papers in the (7) geological survey and applied field geosciences field can overall be called the “integrated strategic type”, but they include several types such as the individual strategic type and the individual strategic and field fusion type. There are also those that transform from the breakthrough type to the fusion type as the types change and develop over time. The research may progress according to the shifting social demands, the geological phenomena are often understood as complex systems, and the interactions tend to take place in a spiral structure.

Lastly upon the analysis of the 50 papers, we extracted the issues for the synthesis method. First is the “synthesis method in *Synthesiology*” (see figure). There is the process of strategy and scenario → selection and combination of elements → testing in society, but it was found that another important factor is the “feedback”. The examples of selection and combination of the elements can be categorized into the aforementioned “aufheben”, breakthrough, and strategic selection types.

Second is the “property of the research field and synthesis”. In the fields such as physics, chemistry, mechanics, device technology, and metrology, the elemental technologies are clearly defined and the synthesis method is relatively simple. There are also complex systems such as environment, energy, and geology. Then, there are complex interactive systems such as biotechnology, human technology, and information technology, where the synthesis method changes and the complexity increases.

Finally, the “introduction into society” is our main issue. To introduce a research result into society, a social action that is independent of and collateral to the technological development enters into the factor, as well as the addition of values such as emotional aspect and need of an impressive concept, aside from the function. It may also be necessary to promote autonomous synthesis by sowing the seeds of elements while giving up short-term profit. Not only is it a matter of technology, but it will be also important to respond to the feedbacks from society. I propose such issues for our discussion.



[Panel discussion]

Motoyuki Akamatsu (Senior Editor, *Synthesiology*, AIST)

The objective of *Synthesiology* is to publish papers that describe the synthetic researches conducted according to the scenarios that outline the process of creating the technology that will be used in society. Therefore, I hope we may get a glimpse of some synthesis methodology to create innovations.

We shall hear from Dr. Kobayashi who proposed the issue, Dr. Suzuki who promotes the idea of meta-engineering at the Engineering Academy of Japan, Mr. Kitayama who has experience in the R&D of optical network, and Mr. Ito who will explain the history of the car navigation system. Then, I would like the participants to discuss the synthesis methodology for introducing the products into society.

Proposal of meta-engineering

Hiroshi Suzuki (Technology Executive, GE Energy; Chair of the Task Force for Committee on Technology Policy, Engineering Academy of Japan)

The Engineering Academy of Japan is a group of leading engineers and was established to contribute to the advancement of engineering and technological sciences in Japan. I am leading a study group there and proposing an idea of “Meta-Engineering”. Recently, I feel that the definition of engineering has been fixed as seeking optimal answers only within a given condition or constraints. Here I find two problems. The first problem is that this condition is regarded as a given and irremovable. The second one pertains to optimization process. Optimization falls into global optimization and partial optimization. I feel that people tend to fall into local optimization that would not lead to a radical solution. Assuming that these two bottlenecks might prevent the sequential occurrence of innovation in Japan, our group was determined to review “Engineering” and named this concept “Meta-Engineering”.

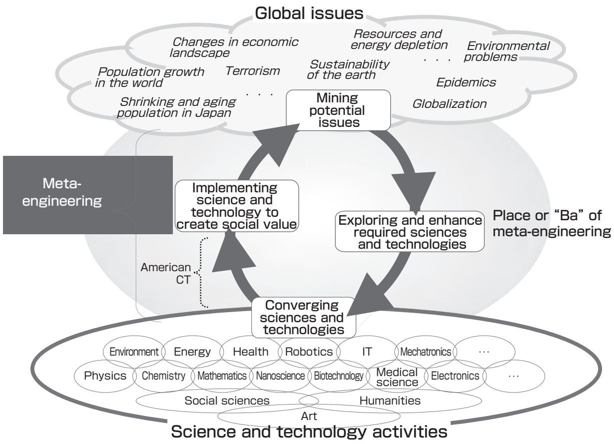
When people seek an optimal answer within a given condition, they might focus only on “How”, but “What” should come before “How”----this inspired me to get the idea of “Meta-Engineering”. Some people say that we should make innovation happen taking full advantage of Japanese manufacturing, and the word “manufacturing” makes most people think about “how we make things”. However, what is important is “what we make” and “why we make it” in the background.

In line with the implementation of the Third-stage Basic Plan for Science and Technology, we see some visible results in science and technology. Each individual result is respectable, but it is hard to think of the innovations that have recently happened in Japan. A single respectable technology or science comes out in Japan, but is not converted---this is the impression that I have.

I use the word “meta-engineering” for the Japanese word *komponteki* engineering or down-at-the-root engineering.

Getting back to the basics of Engineering, we firstly think about an issue. We might have seized visible issues, or issues at hand, but there might be more radical and invisible issues behind them. These issues should be our targets. It is important to see them from a bird's eye point of view in efficiently implementing science and technology on the issues.

First, pick up a potential issue and consider what kind of technology and science are necessary. Then, investigate if any of the existing technology or science would be useful in addressing the issue. Since the recent issues are more complex and difficult, it may be hard to solve the issues in a single science and technology field. So, science and technologies converge, and social values are created by implementing them in the real world. And then, a new issue will emerge, and we go through the same process to create the next social value. I think that the dynamic and spiral process is a key driving force for innovation.



Passive optical network and fiber to the home

Tadayoshi Kitayama (President&CEO, Mitsubishi Precision Co., Ltd.; former Vice President of Communication Systems Business Division, Mitsubishi Electric Corporation)

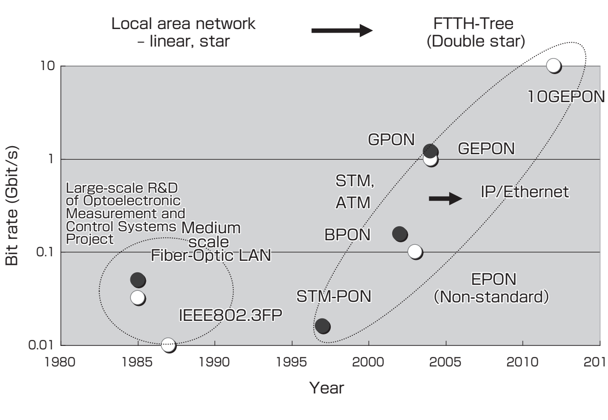
I think many of you are already using the Internet through optical fibers connected between your home and a telephone company office or an internet provider site. This fiber optic access system is called "fiber to the home (FTTH)". FTTH system is composed of optical fibers, optical couplers to tap optical signals from a central office, and terminals. This network configuration is called passive optical network (PON). We first conceived PON in the1980, and it took more than 20 years for it to materialize. We got a hint from satellite communication that was composed of the geostationary satellite and earth stations. In the Large-scale R&D of Optoelectronic Measurement and Control Systems Project administrated by the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry, the primary data network consists of loop-configured passive fiber-optic transmission system equipped with optical couplers, burst mode optical transceivers, TDMA processors for N:N communication and interface adaptors for data-terminal equipment were developed(1980-1985). The star configured passive optical networks were also adapted to Ethernet-base fiber optic local area networks in 1987. In the 1990s, the star configured passive optical networks were chosen as a network topology of FTTH because of its cost effectiveness and upgradability in the future.

In the development of FTTH, there were two candidates of multiple access methods of PON, One is the asynchronous transfer mode (ATM) which was the ITU-T telecommunication standard that efficiently multiplexes telephone and Internet services. The second is the Ethernet-base random access method which is the IEEE standard and popular interface of computer communication systems. In Japan, the Ethernet was chosen because it would become a more familiar and less expensive interface than ATM. By Voice over IP technology, Telephone services are easily multiplexed with Internet services. The transmission bit rate is 1 Gbit/s and will be going up to 10 Gbit/s to multiplex wider services like video communication services.

It took about 25 years to get here. Why did it take 25 years? We had to wait for the innovation of optical and electrical devices. Standardization of PON needed to be established. The Internet demand had to grow and communication carriers had to change business models from telephone services to internet access services.

The continuous technical innovation of PON for over 25 years could not be handled by a single company. The seed sowing of the technology was supported by the government as I described. Challenges to commercialize fiber-optic Ethernet were carried out through cooperation between a communication carrier and system vendors. FTTH standardization and its development were strongly promoted by a communication carrier. But it was the open collaboration with system LSI vendors, optical component vendors and equipment vendors to speed up the development and reduce the burden on individual vendors that enabled short term development and commercialization of PON base FTTH.

Development of passive optical network



In the future, as the scale of required resources for new technologies development will increase, technological seed sowing led or supported by government will be more important than now. In commercialization stage, open collaborations will be effective and inevitable.

The case of car navigation and route guidance system

Hajime Ito (Former Managing Director, Yazaki Meter Co., Ltd.; former General Manager Body Engineering Division, Toyota Motor Corporation)

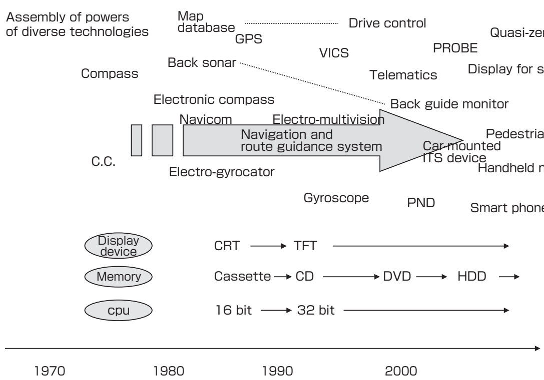
The precursor of navigation was the celestial navigation using a marine sextant and the radio navigation for aircrafts. In thinking about measuring one's present location and which way to go, these are highly important technologies in the development of automotive navigation.

There is 30 years of history in automotive navigation and route guidance system. The early automotive navigation was dead reckoning, where the "present location" was entered and the direction sensor was used to determine how one could reach the destination by following the directions. It is surprising that the three Japanese automobile manufacturers came up with similar technologies and products at the same time around 1980. The companies were searching high and low for various technologies, and realized that they could do certain things using certain technologies, and started to create similar things at once. I have been involved in design for about 20 years, and I repeatedly experienced the situation where similar products appear within a span of a year. I think "corporate competition" is the keyword. In the latter half of the 1970s, various government agencies including the Ministry of International Trade and Industry conducted research on some of the functions of the current navigation. Navigation appeared in 1980 as the crystallization of various technologies including display, memory, microprocessor, and others. Since then, the product power of car navigation increased, it became multifunctional, and became an essential product for cars. For the device to be installed in the car, it had to be incorporated in the design of the automobile, and the automobile companies began to install it as standard equipment.

In the technological field, navigation is considered as a field of intelligent transport system (ITS). The team developing the ITS and the team standardizing it are working side by side, to develop the product, standardize, and to advance it as the world standard. The ITS Promotion Council is a Japanese organization to discuss ITS among government, academia, and industry. The activities are done under the supervision of this organization, and the manufacturers are not working individually. This is an important point.

For human factors, the HARDIE guideline was created in Europe, but Japan had made many navigation systems after 1980, and the guideline of the Japan Automobile Manufacturers Association (JAMA) became the basic guideline of the world standard or the human factor requirements. For example, one cannot set the destination while driving, the map display disappears when one enters the community road, the prefectural roads are shown preferentially in the route guide, or one cannot watch TV while driving. These conditions created in Japan became the world requirements, then became the requirements considered by the ISO, and as a result, became the guideline of the Ministry of Land, Infrastructure and Transport. Since the navigation is not a prerequisite for driving, it is placed some distance from the center of driver's vision, yet it is placed in a fairly visible place to prevent accidents if the driver looks at it while driving. I described the display requirements earlier, and the manufacturers must, of course, follow the requirements, but they must provide added value to their products in other areas. It will eventually become safe to view it while driving and be useful to the driver. That will be the future automotive navigation product.

Evolution tree of automotive navigation



[General discussion]
What is the difference between the "what" in the 80s and the present "what"?

Kobayashi

Dr. Suzuki has mentioned in meta-engineering, that the most important thing in taking the bird's eye view is "what to do". The Large-scale R&D of Optoelectronic Measurement and Control Systems Project had been underway at around 1980, but what is the difference between the situation at that time and the current "what"?

Suzuki

"What" arises from "why it is necessary". In the history of electrical engineering, I analyzed how the technology was born from a certain social background and social demand. The air conditioner was first used for cooling only, but with the development of the inverter and heat pump, it became usable for both cooling and heating. Currently, there are concerns for health and human factors. We must spend our effort on learning the social background of what the society needs, what is important in our daily lives, and "how" to make the "what". However, recently we've been neglecting that and we seem to be thinking only about the "how", and I hope we can get back to basics.

Akamatsu
Is the "what" in optics to realize large volumes of communication at once?

Kitayama
In the early stage, loop or ring configured optical fiber communication systems were introduced to computer controlled manufacturing plants because of their high electromagnetic immunity. As the number of computers and terminals increased, loop or ring configured optical networks needed higher bit rate, larger number of communication nodes and cost for the system soared. We thought downsizing and reducing the cost of the communication nodes were necessary to construct a larger area optical network. We thought PON and multiple accesses scheme would be the most promising architecture for FTTH.

Ito
The 1980s was when motorization exploded. It was a time when roads were not organized and the road signs were all messed up. The available maps were crude. It was an era when many problems could be solved through technology that allowed one to find out where he/she was and which way he/she was heading. At present, navigation and route guidance system is one of the instruments on a car, and it has several functions. However, I do not think that it is important to just think of safety and environment, nor do I think that navigation has been perfected. I think there is room for research in route guidance that matches the human perception, is ergonomically sound, and allows reduction of traffic jams.

Was the government support for the R&D project effective?

Akamatsu
When the automotive navigation was realized, can I assume that the government support for the R&D project was effective?

Ito
I think yes. Back then, I think there was antagonism among the government agencies, but there was a good and close relationship for the ITS field, and the Cabinet Office supervised the activities. ITS Japan played the role of linking the private companies, government, and the academia. There are participations of 180 private companies. These companies cannot do what they want. The entire thing must be coordinated to set the key competitive areas. I think we are in such a situation.

Kitayama
In trunk line communication systems, it was very clear that by introducing higher bit rate optical transmission technologies, the cost of communication would remarkably reduce. But the market was not so big compared with access network. While many people thought that high-speed optical communication technologies would be available even in access networks in the future, nobody conceived to develop optical access network by themselves because many breakthroughs would be necessary, especially about passive networking and cost reduction. Large-scale R&D of Optoelectronic Measurement and Control Systems Project had an important role to trigger the optical network technology development.

Suzuki
Exploring an invisible issue, identifying necessary science and technologies, converging these science and technologies if necessary and creating social value by implementation cannot be all done by one person or one organization. Therefore, it is necessary to consider how to make a "place or "Ba" of Meta-Engineering" or an ecosystem where various companies can participate. In this case, I think the national project made a significant contribution.

Ito
I think it is true that everything went fine because of the cooperation from the government organizations, and it will continue to be so. Now, for example, VICS is the information obtained from the police vehicle detectors. Since tests have just begun for the probe that collects information from the vehicles on the road for the next-generation traffic jam information, there must be cooperation with such organizations. Another point is that the Japanese navigation is based on maps, but the Ministry of Internal Affairs and Communication and the Ministry of Land, Infrastructure and Transport claim that using the map just for navigation display is wasteful. I hope we can discuss such things in the "place".

Kitayama
Before, system manufacturers had to develop the semiconductor process, optical devices and ASICs and software by themselves. Recently, the developing period has become short and the scale of development has become large. There is a limit on resources or risks a company can manage. I think to win the competition in commercialization, good cooperation in an open environment is very important. Not only large companies, but also venture companies need to cooperate with each other. In an open environment, it is essential to build a trusting relationship, and to cooperate to run the project until an achievement is made.

Ways of selecting and combining the successful elements and universalizing them

Audience

I think the discussion is drifting into the particulars. The selection and combination of the elements of the "synthesis in *Synthesiology*" discussed by Dr. Kobayashi is very important. You talk about aufheben, breakthrough, and strategic selection types, but which would survive? In the Theory of Inventive Problem Solving (TRIZ), or as Dr. Kikuya Ichikawa who wrote the *Sozo Kogaku (Creative Engineering)* says, there is a pattern in the evolution of technology, and those that do not follow the pattern fail. I want *Synthesiology* to mark out the thought process toward success. Since we are doing things in a bottom-up style, I've been a bit concerned. I think we can start from a hypothesis.

Kobayashi

Our goal was to get there, but currently we don't have enough accumulation of case studies. There is interpretation involved in the consideration for synthesizing technology, and I think hypothesis is included in the selection and combination. Also, it could be seen from the analysis so far that the cycle must be turned until the final implementation in society.

Suzuki

In *Synthesiology* Vol. 1 No. 2, the interview of Professor Richard Lester by Dr. Kobayashi was very interesting. Professor Lester mentions that not only analysis but also interpretation is important in "innovation". Innovations occur as many things are adeptly interpreted, but he also says that innovation does not occur by interpreting alone. Innovation must be made by striking the balance of analytical and interpretive areas. I think this is where *Synthesiology* can be powerful, and I am hopeful.

Ono

I think the comment from the audience presents a lofty ideal. We also purport the ideal, but *Synthesiology* as a journal is rather a framework or forum for discussion and presentation of opinions. There are two objectives with *Synthesiology*. One is that while pure basic research has been established as the methodology for science, we do not know what exactly constitutes originality for the applied and integrated research, and there is no method for seeing whether a certain result is true. I think *Synthesiology* is a forum to address such issues. That is the first objective. The second objective is for people in various technological fields to present and exchange strategies and integration methods. People can show each other what has not been established with an integrated research or discipline, and seek solutions in a bottom-up style. *Synthesiology* provides chances for such discussions, so please submit papers of your thoughts. It's like an advertisement for the journal, but that is what we would like to do.

To create an environment for thinking about "why" and to overcome the barriers

Audience

Many people indicate the problem of education as the cause of not being able to think "why". After World War II, the Japanese were educated to work hard on the problems that were laid before their eyes. That was fine during the era of catching up (to the United States and Europe), but that does not work now. What should we do?

Another point; considering the "why", I think to get a breakthrough, we must do things by trial and error, but if one wants to do something in Japan today, there is always some barrier or regulation. There are so many things that can be learned from failure, but we can never say "I failed". Do you have any suggestions for overcoming such barriers?

Suzuki

If there were answers to those questions, I would certainly like to hear them. There is a book by Mark Stefik called *Breakthrough*. I translated it. Stefik states "the researches we need now are 'radical researches'". The basic research until now was a study of a given research subject, the solution was sought, and one thought of how to overcome a barrier when he/she encountered it. In application research, when one came against a barrier when attempting to realize something, the product was completed by taking a different method that bypassed the barrier. In radical research, if one encounters a problem, the problem is studied as a subject, and the knowledge will expand although the research subject may change. I think it is necessary to solve the problem by introducing other technologies and fields as well as social technology.

As for the suggestion for overcoming a barrier when considering the "why", it is perhaps a bad habit of the Japanese to enter from the "how". I think *Synthesiology* will be an interesting place or "Ba" that may provide a chance to see the "why" once again. I hope people will take advantage of this place.

Akamatsu

We are thinking of various methodologies for utilizing research in society, and are working to establish synthesiology as one of the ways. Please continue to support our efforts.