Lecture at the 27th Conference of the Japan Society for Science Policy and Research Management

Methodology of the introduction of technology to society from the analysis of papers published in *Synthesiology*

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***Synthesiology* Editorial Board**

Participants Naoto KOBAYASHI, Waseda University (Vice Editor-in-Chief, *Synthesiology*)
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Kobayashi

It is almost five years since *Synthesiology*, a journal that aims "to establish a synthetic methodology that allows the researchers to conduct effective and efficient research that is useful to society," was first published in January, 2008. This journal requires "a description of the social value of the research goal," "a presentation of a scenario and a selection of elements," and "a correlation of elements and their synthesis and integration." We expect that the originality of the papers will be represented by the created scenario, the selected elements, and the method by which the elements are synthesized and integrated.

We have analyzed types of synthesis for 70 papers submitted so far in the six fields: environment and energy; life sciences and biotechnology; information technology and electronics; nanotechnology, materials, and manufacturing; metrology and measurement science; and geological survey and applied geosciences. The basic types of synthesis of elemental technologies are "aufheben type," "breakthrough type," "strategic selection type," and "spiral type."

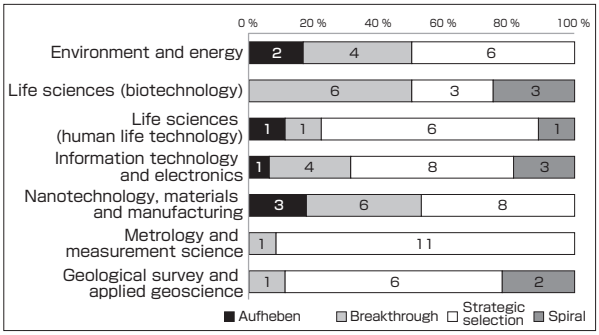
"Aufheben type" is sublation proposed by Hegel, that is, the progressive integration of opposing elements, and we thought that it might also occur in technology. One example is the integration of glass mold and imprint methods. Although the glass mold method was conventionally applied to flat glass, it was not suitable for small structures. On the other hand, the imprint method was used to transfer structures of molds, but it was not suitable for use at high temperature. The two methods were combined to develop a new nano-level processing for glass. In the "breakthrough type," the peripheral elemental technologies are added to the main elemental technology to produce an integrated technology. For example, in "creating non-volatile electronics by spintronics technology," the double breakthroughs of the development of a new material and a new device as well as the development of a mass production technology were achieved. In the "strategic selection type," several elemental technologies are selected and integrated according to a preconceived strategy. The example of the "spiral type" is bioinformatics in the life science field. By creating a pipeline where the knowledge of the genetic characteristic of the G protein coupled receptor (GPCR) was developed and applied using a large-scale computer technology, the issues were extracted as this information was publicized and actually used, and the extracted elements

were fed back for product realization. This is a new synthesis method that we did not originally consider.

In the six fields, the strategic selection type was the most prevalent, and 34 papers out of 70 were of this type. There were 12 breakthrough types, 7 aufheben types, 2 spiral types, and the remaining 15 papers were combinations of two or more types. From studying these papers, we were able to see, as the basic types of technological synthesis, aufheben, breakthrough, and strategic selection, and we also saw the importance of the synthesis method called the spiral type, where the interactions with society were repeatedly fed back to the research process. Also, it became clear that the synthesis type of technology was not uniform, but many layers of types could be combined, and that there were characteristic synthesis types for certain fields.

I have so far discussed the introduction of technology to society, so we shall now discuss the use of technology in society.

Result of categorizing into four types by fields
(Combinations are counted with overlap among various fields/types)



Akamatsu

Even if something is a wonderful technology or product (process) that may fulfill a social demand, it may not be easily accepted in society, and it does not necessarily spread easily throughout society once it is introduced.

Using the *Synthesiology* papers, we analyzed how the technologies and products were introduced to society from the perspective of the relationship between technology and demand. The cases can be divided roughly into the case in which "the social demand is clear" and that in which "the social demand is unclear."

Dr. Naoto Kobayashi

First, in a case where "the demand is clear," as it was explained earlier in "the development of a new material and a new device for the development of a mass-production technology" in spintronics, not only the elemental technology for high-performance, high-speed, and low energy consumption memory that society wanted, but also the manufacturing technology that the companies could actually use was developed. Another example where the usage in society is clear is the traceability system of measurement standards. If the technology is expected to lead to a product, stable performance is necessary, and the R&D should be done concurrently with the manufacturing technology to enable mass production of the industrial product. Another important perspective is that it is adaptable with minimum change to the existing manufacturing process. In the example of measurement standards, it employed an easy-to-use design that corresponded to the supply system of the technology.

Next, in the case where "the social demand is unclear," one way of execution is "to make a product and to demonstrate it." The examples are making an impact by creating a prototype of a portable and compact standard of length, or a prototype of a real-time, all-in-focus microscope. There is also the method of "having people try the product." This includes manufacturing organic nanotubes in the amount that could be provided as samples, or to have people use the Cyber Assist (context-dependent information service) at exhibitions or events in conditions that were close to the real situation. These examples impressed people by giving actual forms to technologies and by showing that products could be fabricated using the available technologies. As a product is used in diverse ways, the adaptability of the technology can be investigated and technical issues can be extracted.

There are cases where "the demand is understood but there is hesitation." I think there are many such cases, and we have "to wait for the people to understand the usefulness" or "to just go ahead and do it." The "evaluation device of UV protection cosmetics" was a case where the basic technology was completed and the demands were understood, but we had to wait patiently since time was required for decision making. In the "dependable information system," not only were the information necessary on site recognized and explained, but also the importance and values were shared by actual demonstrations.

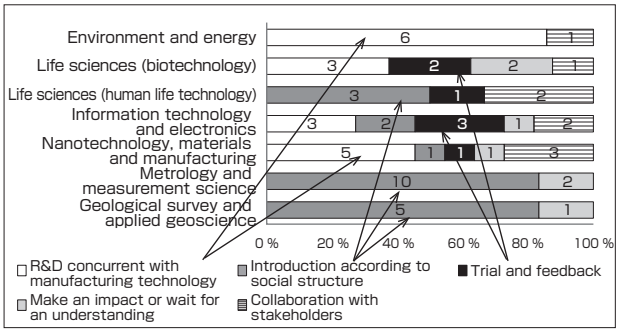
In the next phase, the product is made and set in society. In the "development and diffusion of the IH cookery and cooking system," value was added to the product when a cuisine specialist who was a sensitive lead user proposed new ways of using the product. Also, in Japan where car

navigation systems are prevalent, the technology diffused not only through the effort of the car navigation manufacturer, but also through the collaboration of diverse stakeholders including the government, sensor manufacturers, map publishers, and others.

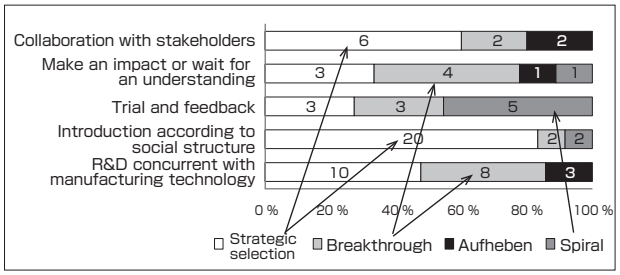
There are special characteristics of social introduction for different research fields. In many cases of the environment and energy field, the manufacturing technologies were developed concurrently. Since many energy problems involved CO_2 emitted by industry, the manufacturing technology development became important because of the need to solve the energy issues as a whole. In nanotechnology, materials and manufacturing, the manufacturing technology itself was the target. On the other hand, in the life sciences (human life technology), metrology and measurement science, and geological survey and applied geoscience fields, the technologies were mostly introduced by adaptation to the social structure. Many developments in the life sciences (biotechnology) and the information technology and electronics fields were spiral types that involved trials.

For the social introduction of the research results to society, it is important to instigate consecutive synthesis toward social introduction. Different approaches are necessary for different cases such as for cases where the social demand is clear or unclear or for cases where the expansion of industry is attempted. Considering "the creation of innovation from social introduction," it is necessary to accumulate analyses of such synthesis examples, to analyze the dynamism, and to study how the scenarios should be constructed.

Characteristics of social introduction in each research field



Relationship between social introduction and technological synthesis



Audience

Isn't there a discrepancy between the self-evaluation of the researchers and the external evaluation by the industries that use the results? I feel that such discrepancy is the reason that prevents innovations to occur.

Akamatsu

By writing a paper for *Synthesiology*, one often looks back on how one thought about the feedbacks to society. When you are able to clearly evaluate the degree of systematic thinking that was done, I think it would become easier to talk to society or companies.

Audience

I think basic research can be monitored by the number of citations of the paper. For the application to society, is there any monitoring method that can be automatically tracked?

Akamatsu

As one cannot tell whether the research results written in the conventional journals will actually be used in society, *Synthesiology* exists as a journal that allows the description of the process toward actual use. Although there is a matter of being lucky or unlucky in social introduction, a large factor is how much effort is spent or how much of a mechanism is created to control luck. It is difficult to measure this in a quantitative way, such as by the number of output. However, I think it is possible to evaluate the process. I think we can evaluate it based on whether the necessary process is taken with consideration of the social introduction.

Kobayashi

We believe it is important to accumulate case studies. I think this is where the corporate people excel, and I hope you will produce many papers of this nature.

Dr. Motoyuki Akamatsu