Future of *Synthesiology*

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We have reached the tenth anniversary since the launch of the journal *Synthesiology*. During these 10 years, the journal published many papers on the results of synthetic research. Papers were also published on the proposals and research that analyzes the essence of synthetic research[1][2]: What is synthesiology? What is the structure of synthetic research? What are the conditions under which a research paper may become useful knowledge to society? Such papers provide important guidance to those who are attempting to write papers on synthetic research. Synthesis is not only an important intellectual activity for people who produce useful things and contribute to society. It is also becoming clear that the results may bring forth major effect on society as well as the natural environment and earth, and there is increased consciousness that synthetic actions may have adverse effects on society and nature. Against this background, I would like to reflect on the significance of the journal that was launched 10 years ago with the hopes that the scientific community and society will recognize synthetic research, a unique type of research, similar to scientific research that is backed by a long history.

1 Scientific papers

When I first became an editor at an engineering society, the following was said: “You cannot write a paper on just making something.” In fact, such papers were rejected for that very reason. There was much discussion on this subject, and I think the consensus that emerged through the discussions was that the thought process that goes into making something is “not scientific.” This mode of thought originates from the idea that the research that is published as papers should follow scientific methodologies. In practice, many artifacts that are human inventions and had great impact on the world, including machines, electronic devices, and materials, were perhaps made by using the knowledge of science, but were not necessarily created in accordance with the officially recognized scientific methods. In fact, the making processes have never been presented to the world in a paper form, and only the results have been manifested as artifacts or in the form of patents in part. For example, no one wrote a paper about the steam engine, but it appeared as a machine, and was put to work thereafter. In science, a paper is accepted as a scientific result, which in turn is recognized as official knowledge, because research has been conducted based on officially recognized methods. However, there is perhaps no officially recognized method for the usage of knowledge, and therefore, the results obtained by using the knowledge is not recognized as official knowledge like the results of scientific research, and therefore, documentation of the use of knowledge cannot be accepted as a paper.

Put in simple terms, scientific research is a process of coming across a phenomenon that one does not understand, and finding a principle that drives this phenomenon and provides a comprehensive explanation. If the discovered principle is new, it can be registered as something that may become a scientific law. Scientific knowledge is a set of laws, and the objective of science as a whole is to systematize the set of laws. Humankind discovered this method over a long period of history. A phenomenon that cannot be understood is carefully observed as much as possible, and assuming that there is a general principle that generates the observation result, an attempt is made to explain the phenomenon using assumptions. If an explanation is provided, the principle is called a hypothesis and is set as a candidate of law. The hypothesis remains a hypothesis unless it is overturned by some other phenomenon, and it will be officially called a law if it becomes incorporated without contradiction into the system of laws. Speculation using this law is recognized as being correct.

2 Foresight of *Synthesiology*

On the other hand, human activities including making a new machine or device, adopting a new mode of behavior, or establishing a set of regulations, collectively called “artifact making,” is an act of creating phenomena that are meaningful to people. This meaningfulness is the function of artifacts. In general, this meaningful phenomenon is synthesis of diverse elemental phenomena. The selected elemental phenomena not only depend on scientific laws, but also are gathered through empirical knowledge, conception, insight, intuition, or social motivation, and anything that may be unexplainable by science can be incorporated freely. This is clear from the example that a steam engine was created before the laws of thermodynamics were established, and even currently, one

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does not know all the scientific laws of various phenomena that support the artificial system in which efficiency is achieved in economic activities through the introduction of information systems.

As it can be seen, functions that one wishes to have are created by selecting and synthesizing necessary phenomena, and one may select the phenomena as long as he/she knows about them, without knowing the laws that govern the particular phenomena or without having a systemized methodology for combining the phenomena. The inability to express what drives the process of artifact making as a general methodology is the reason that one cannot write a paper just about making a machine.

The author believes the reason for “not being able to make an artifact well” is because humankind does not know exactly how an artifact is made, or one cannot provide a lucid explanation for the making process like for science. There is a reason for it being considered not done well, despite the fact that we are producing large amounts of artifacts. That is because several different things are made for the same intention, and it is impossible to evaluate the validity of the things that had been made. As a result, the evaluation is left to society, but looking at examples in which a flood of artifacts causes environmental destruction, it cannot be said that we are doing it well.

Moreover, we have already passed the stage in which we can simply say that we are doing it poorly. Creation of artifacts has given humankind benefits as intended, and that is the basis of prosperity of humankind. On the other hand, many problems are generated and shared by people, a representative one being global warming, but there are other issues for which urgent measures must be taken. These are side effects in which unintended functions were created, and many present the limit of earth’s tolerance (planetary boundary, J. Rockstrom[3]) from the viewpoint of resilience. They include global problems such as resource depletion or increased natural disasters, as well as regional problems such as poverty, wealth difference, famine, disease, short life expectancy, and conflicts. Looking at their causes, they are all based on human activities. Modern competitive industry that applied scientific knowledge to industry created an uneven distribution of technological levels and generated wealth gaps. Poverty is born in such a setting. The competition of unlimited expansion due to increasing population affected the air, sea, and ecosystem, and as a result, it is causing the deterioration of the earth environment. Currently, humankind has become aware of the problem, and although it took decades to acknowledge global warming, we have reached a global agreement to take countermeasures. While the newly proposed Sustainable Development Goals (SDGs) of the United Nations is not for the world to take action after agreeing on the driving principle as in global warming, but points out the immediate problematic phenomena and urges the region to solve the problem.

In the case of global warming, the policy is to restrict the amount of carbon dioxide emission to remove the inconvenient phenomena that have been generated. On the other hand, SDGs is a policy of working to solve the problem utilizing the experiences of the regions that succeeded in solving similar problems. Basically, the solution is sought by suppressing activities or by transferring existing knowledge. Are suppression of existing methods and regional transfer of knowledge the only methods for solving the current earth problems that are generated by artifact making?

3 Philosophy of *Synthesiology*

Recently, design orientation is becoming a topic in university education. This is based on the thought that one must increase the ability to design in order to meet the social demands, and the author thinks there is an important meaning in this. Design is a concept that covers the act of “artifact making” in a wide sense of the meaning as explained above, transcending the realm of development and design conceived conventionally by engineers. It includes planning for various activities in society, for example, proposal of laws and policies, business planning, conceptualization of artistic production, university policies, disease treatment, and personal life plans. These are synthetic activities that are contraposed to analytical activities in science. It also means that “becoming adept” at these activities is now recognized as a social goal.

Hence, design orientation requires synthetic action to be not just implicitly recognized but to be explicitly recognized as something that is important to people, and then be objectified and be thought about. If that is the case, *Synthesiology* is already ahead by 10 years concerning the current rising interest in design, and it can be said that many valuable findings pertaining to design have been accumulated.

What are the papers published in *Synthesiology* like? The author surveyed the papers a few years after the launch of the journal, and they will be described as follows.

A scientific paper takes the following form: a subject is selected, a phenomenon caused by the subject is observed, observation results are analyzed, the phenomenon is explained by existing laws or some new law is proposed as a hypothesis, and application of research results is referred. For example, in life sciences, the role of a component within an organic phenomenon is clarified, and treatment for a disease is proposed based on this knowledge, in the course of clarifying how components work in an organism.

Though, in a scientific paper, the “application of knowledge” is discussed in the final chapter, in *Synthesiology*, "application of knowledge" is written first as what is demanded by society. First, why society demands such technology is stated. Scientific and technological knowledge needed to solve an issue is searched, and the knowledge that lacks is pursued by new research projects. Or, hidden knowledge is excavated by freely roaming in society. Based on such a background, a scenario is written as a hypothesis, but the description must be logical and consistency of meaning is required.

A scenario is a hypothesis that presents social issues and offers solutions. A paper is written when results are obtained as realization of the hypothesis. The hypothesis induces unique R&D, and the usefulness of the results obtained from research is confirmed, and the written paper includes the originality of the hypothesis and the originality of the solution.

The structures of the submitted papers are unique and the contents are diverse, but the viewpoints of research have something in common. The viewpoints can be categorized as follows: new function(s), risks associated with the new function(s), design of an artifact (in a wide sense) to realize the function(s), manufacturing based on the design, unique measurement, and social technology to implement them in society. Each viewpoint has original points or items. While the contents vary according to paper, the characteristics of the paper's intent can be understood by writing out the viewpoints of research along with the items using categories obtained as a result of a survey as a template, and by specifying the corresponding items. For example, the paper on antifreeze protein in Reference [4] that was published in Volume 1 Issue 1 can be written out as Fig. 1.

The viewpoints of Fig. 1 should be realized in research, and the viewpoints necessary for achievement are shown on the template. In this research, the goal of developing an excellent freezing method necessary for storage and transportation without damaging the quality of foodstuff is realized by using scientific knowledge discovered in basic research,. When shown like this, the relationship with other research with different goals can be visualized. In other words, synthetic research that was thought to have no mutual relationship with anything else can be understood as something that does have a common, original structure and necessary information. It is hoped that such examples will rectify the situation in which scientific research that follows scientific methods is trusted and papers can be published as scientific papers as a social rule, whereas synthetic research not following scientific methods does not have a journal in which to publish. This is discussed in detail in papers of References [1] and [2] by Ono, Akamatsu, Kobayashi, *et al.*

The viewpoints being the items that must be realized means that they are the required functions in design in a wide sense as mentioned in this chapter. If items can be formalized as a template, this allows expectation of adept synthetic activity as mentioned above by creating "rules of requirement that covers all viewpoints" and allows avoidance of aforementioned side effects as well as realization of goal functions. This can be considered the philosophy of synthesiology.

If this becomes possible, the removal of side effects shifts to regulation of *post facto* actions and transfer of knowledge, and these can be embedded within the design of action. This must be considered particularly in SDGs planning. There, diverse knowledge and technology will be applied to new regions, but if they are applied without considering the uniqueness of the region, dangerous side effects may be forecasted. The removal of risks of side effects at the design stage is essential.

1. Function $\boxed{\text{New function}}$ Strengthening function
Downsizing Long lifespan High reliability
Low environmental load Energy saving
Resource saving 3R

2. Risk Nano-risk $\boxed{\text{Environmental pollution}}$
$\boxed{\text{Safety}}$ Digital divide

3. Design Research strategy $\boxed{\text{Theory}}$ System
Discipline design Discipline-transcending design
Computational science Knowledge base

4. Manufacturing $\boxed{\text{Mass production}}$
Spatial arrangement Manufacturing machine
Standard Processing method (Removal, addition, deformation, joining, separation)

5. Measurement New method Microscope
Structural analysis Visualization
$\boxed{\text{Environment/lifespan test}}$ Simulation Prediction
Total observation

6. Social technology Science and technology policy
Research institution/organization R&D investment
Industry-academia collaboration
Intellectual property rights $\boxed{\text{Development cost}}$

Information & communication
Nanotech materials
Energy & environment
$\boxed{\text{Life sciences}}$
Medical sciences

Fig. 1 Viewpoints of synthetic research

4 General design theory

Here, we again look at the thought on papers that rely on scientific logic that conveys that “one cannot write a paper just about making something.” In science, research methods are openly shared among scientists, and the research that follows these methods is written as scientific papers, and this is the basis that guarantees the validity of the papers. In contrast, synthesis uses methods that include experience, intuition, insight, and feelings that are elements not recognized as being logical, and therefore one is told that the results cannot be considered valid.

This requires some explanation. In scientific research, a conclusion is reached for a certain phenomenon through experiments that eliminate noise, observation with as much precision as possible, and discussion that follows deductive reasoning. Since the precision of observation is always subject to error, inductive reasoning is also used. Up to this point a paper can be written, but the paper may expand the application range of the results to phenomena for which experiments have not been done. If the paper states that the finding is a law, then a hypothesis is proposed, but it is said that the thought process involved can only be from intuition or insight. Here, deduction and induction are not useful as reasoning, and hypothesis formation (abduction) is used. Abduction is fallible, or subject to mistakes. A proposal of a hypothesis, which is the most important part of scientific research, is a fallible abduction in terms of reasoning, and in this case, the thinking process of the scientist is mainly intuition and insight.

How synthetic research is different from science should be questioned. The answer is “it is the same.” However, the argument that synthesis cannot be written as a paper is not necessarily wrong. In fact, in scientific research, which part is abduction in the thought process is explicitly shown in the law proposed by abduction. Moreover a hypothesis is not negated unless there is objection raised by other researchers or the researcher him/herself. It is gradually recognized as law after several verifications, and it is shown that the relationship to other related laws is consistent. Of course, the law may be rewritten through new viewpoints, and that is the progress of science.

Considering that science holds such a background, why does the same synthetic research not become papers? That is because the same hypothesis is not confirmed by careful experiments and observation as in science. In the case of science, if confirmation is made within the range of limited experiments, it is temporarily set as a correct hypothesis, and it will continue to be a valid hypothesis unless it is disproved by other experiments. However, in the case of synthetic activity of artifact making, strict experiments and observation with ever-increasing precision are impossible. We have a custom of setting as the primary condition for a created artifact the fulfillment of the desired functions. However, one cannot definitively speak of its validity due to the instability of the place that it is used, uncertainty of observation, as well as the vagueness of interpretation of the functions set as its objective. Moreover, it is extremely difficult to confirm the appearance of “unexpected functions” that corresponds to application to new phenomena in science.

In practice, the evaluation of validity of an artifact is left to society in which the user resides. If the artifact continues to be used without rejection, it is concluded that the artifact is valid. Of course, when times change and the standard of evaluation changes, it may be rejected, but that is the same as the rejection of old theories in place of new ones in science.

From this, a strategy is brought about for having synthetic research accepted as papers. This is a strategy in which the realization process of the goal is clearly stated including the expression of functions set as the goal, the process of finding the elements to realize those functions, the group of phenomena used to realize the elemental functions, and the synthesis of these phenomena. In which place abduction is used is also clarified. It is in a form that guarantees the possibility of criticism at all steps of this process. When the expression that can take criticism is able to face all objections thrown by society as well as the researchers of the same discipline, the synthesis result will be given the status of hypothesis as in science. However, in scientific research, there are many cases in which the phenomenon that cannot be explained is made clear by using existing laws, and in those cases, deductive logic is mainly used. Abduction is the issue when proposing a new law, but in synthetic research, more intellectual work is required than in scientific papers because abductive reasoning must be used in all.

When acceptance or rejection of an artifact is determined at the place of use, it is hoped that social judgment will be made easier if the logical structure of the process of artifact making is explicitly expressed for judgement. In the use of scientific knowledge, for example, in energy issues, quickly providing information to the researchers studying climate change could have been possible by clearly indicating the scientific knowledge known for a long time that burning fossil fuel generates carbon dioxide, even if it was not related to energy extraction that was the function set as the goal. In recent research for the replacement of human action by information technology, the efficiency can be confirmed by experiment at the place of production, but the idea that the living environment will be improved by introducing information technology to homes is made by intuition. In this case, it should be explicitly presented that the effect of connection with external information on humans cannot be explained scientifically, and it is necessary to show society that the evaluation of its effect is unconfirmed. In *Synthesiology* papers, the explicit statements of such viewpoints are written not only as scenarios but also as risk estimation by prediction of functions, and papers are valuable because discussions unseen anywhere else are conducted on issues based on the aforementioned viewpoints.

The conclusion here is that it is important to set the mind on this point of view when writing for *Synthesiology*, but this problem is actually an issue handled in the school of general design that discusses the definition of synthesis. It is expected that research of general design that is different from science and determination of the format of the paper of synthetic research will be done coordinately.

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