# Methodology and a discipline for synthetic research

## — What is *Synthesiology*? —

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In the analytical sciences, several formulations of the discipline such as Descartes' discourse, Kuhn's paradigm, and Popper's falsifiability have been attempted, but such discussion has not been done for *Synthesiology*. The only exception is the series of work by Yoshikawa. Here, I attempt a formulation of the methodology of *Synthesiology* as a discipline by stating that what Yoshikawa calls *Type 2 Basic Research* is synthetic research.

*Keywords* **:** Synthetic methodology, perspective, worldview, language, science, engineering

## 1 Introduction

Ever since Descartes' *Discourse de la Méthode*[1], methodologies for natural sciences have been discussed widely. Natural sciences demand objectivity, and Popper demanded "falsifiability"[2] to guarantee objectivity and stated that only propositions that can be falsified by experiment could be subjects of science. The necessary condition for this is that the system to be observed must not include any observer so that the same result can be obtained by any operator. This means science cannot exist if the system under investigation cannot be separated from the observer.

Kuhn's paradigm theory[3] suggested that the framework is not fixed but is changing as the paradigms shift, and Polanyi's theory of tacit knowledge[4] addressed the fact that natural science is a social activity. While these concepts lead to questions regarding the absolute status of natural science, they did not give rise to discussions on other methodologies, particularly in engineering. The only exception is the series of work by Yoshikawa[5]-[8].

The author learned natural science methodology in high school and university, and only recently became aware that it is not almighty[9]. To study only subjects to which scientific methodology can be applied is like searching for lost items only under were there is a bright light. There exist in this world many issues to which scientific methods fail to fit, and I wish to consider what methodologies can be employed to tackle such subjects. This is the main theme of *Synthesiology*. In the world of crafts, the artist and the work are inseparable (i.e. they do not fulfill the necessary condition of natural science), and in the field of engineering, though not totally dependent on people as in crafts, they cannot be completely separated as in pure science. Here, I shall state that what Yoshikawa calls *Type 2 Basic Research* is synthetic research, and attempt a formulation of methodology as a research discipline.

## 2 Language and thought

I shall consider synthetic methodology from the standpoint of a researcher of information science. Since I consider language to be the essence of issue, I wish to focus discussion on language.

First, I shall discuss *kagaku*. In English there is a word "science," but this does not correspond directly to Japanese *kagaku*. In English "science" and "art" are concepts that overlap as shown in Fig. 1. The origin of "science" is *scientia* (knowledge), and it started as a classification of the study subjects. The origin of "art" is ars (craft or craftsman's skill), and the nuance is close to Japanese *gijutsu* (commonly translated "technology"), and is a concept that includes *geijutsu* (commonly translated "fine arts"). In Japanese, *kagaku* and *geijutsu* do not overlap, and the two words are often used as antonyms. In Japanese, the part "science" minus "art" is generally called *kagaku*. Yoshikawa's *Type 1 Basic Research* corresponds to this part. The part where "science" and "art" overlap is the contact point of *kagaku* and *gijutsu*, or *kogaku* (commonly translated as "engineering").

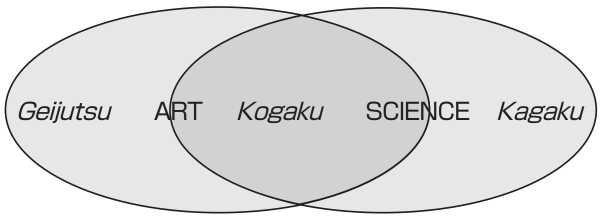


**Fig. 1 *Kagaku* and *kogaku*.**

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Yoshikawa's *Type 2 Basic Research* corresponds to this part. The part "art" minus "science" is called *geijutsu*. However, the word *kogaku* is rarely used as defined here, and in most cases it has come to mean *Product Realization Research* as described by Yoshikawa. The study of synthesis described in this paper is a methodology for the overlap of science and art.

Before discussing the main theme, I would like to explain the issue of language and thought more deeply.

There have been various studies on the effects of culture on cognition[10][11]; its effect on language was addressed by Sapir-Whorf's linguistic relativity hypothesis [12][13].

・ Whorf's strong hypothesis (linguistic determinism): thought is determined by the language spoken by that person

・ Whorf's weak hypothesis (linguistic relativity): categorization of concept differs by language and culture

Although these concepts have yet to be proven, I believe them to be basically correct (at least the theory of linguistic relativity).

Whorf claims that the setting of time and space is also determined by language[13].

Newtonian space, time, and matter are no intuitions. They are recepts from culture and language. That is where Newton got them.(Reference [13], p. 153)

We dissect nature along lines laid down by our native languages. The categories and types that we isolate from the world of phenomena we do not find there because they stare every observer in the face; on the contrary, the world is presented in a kaleidoscopic flux of impressions which has to be organized by our minds–and this means largely by the linguistic systems in our minds. We cut nature up, organize it into concepts, and ascribe significances as we do, largely because we are parties to an agreement to organize it in this way–an agreement that holds throughout our speech community and is codified in the patterns of our language. The agreement is, of course, an implicit and unstated one, but its terms are absolutely obligatory; we cannot talk at all except by subscribing to the organization and classification of data which the agreement decrees. (Reference [13], pp. 213-214)

Spatial cognition has not yet been set immediately after we were born as a baby, but the differences in such cognition gradually occur in the process of learning language such as Japanese or English. The most famous issue is the recognition of color; psychological studies show that how and where one categorizes color depends on the kinds of names of colors in one's mother tongue. Whorf's hypothesis attempts to broaden this to the concept of space in Newtonian mechanics.

Although not as radical as Whorf, it can be readily imagined that the structure of language influences on cognition, particularly on the scientific way of thought. Particularly relevant to this theory is that whether the world can be considered as a *mono* (thing) or perceived as an experience of *koto* (event). Bin Kimura[14] stated that when regarding an apple as a subject, or when a *mono* called an apple is viewed, it is objectified as something separate from oneself. However, when one describes the *koto* of a falling apple, the account includes the concept that the person is experiencing it. Perhaps being related to this, English syntax is noun-centric, while Japanese syntax is verb-centric [15]. It is reported that in Western languages, acquisition of nouns by children precedes acquisition of verbs, but in China, this is not the case, and in some cases they are acquired in the reverse order[16].

## 3 Perspective

Since the linguistic description is closely related to the perception of the world (positioning of oneself), I shall present an example that clearly demonstrates this case. Kanaya noticed the difference between the Japanese and English perspectives, and stated that the two languages describe the environment as follows:

・ English has the perspective of a God

・ Japanese has the perspective of an insect

Kanaya[17] discusses the experiment by Yoshihiko Ikegami in a "Series Japanese" shown on the NHK educational channel. Yasunari Kawabata's *Yukiguni* (*Snow Country*) starts with the sentence:

(1) *Kokkyo no nagai tonneru wo nukeruto yukiguni deatta.*

E.G. Seidensticker, a noted scholar and translator who worked on various Kawabata literatures, translated this into English as follows:

(2) The train came out of the long tunnel into the snow country.

When people who read the sentence were asked to draw this scene, people who read the Japanese sentence (1) drew from the perspective of a passenger on the train (Fig. 2), while those who read the English (2) drew a bird's eye view of a

**Fig. 2 Perspective of insect.**

train coming out of a tunnel (Fig. 3). The difference is not a result of a poor English translation. Although a description from the Japanese perspective is possible, it does not become a natural English sentence.

Next I would like to discuss the issue of the perspective in research. When studying a certain system, where does the researcher stand? In the natural sciences, the researcher is positioned in a place clearly separate from the system (Fig. 4 left). The perspective is that of external observer who stands and observes the system from the outside. Ideally, the behavior of the system should not be affected by the observation, or the method of removing the interference of the observation activity from the result is known. In contrast, Fig. 4 right shows the perspective of internal observer who is part of the system.

According to Ichikawa[18], Westerners enforce a consistent worldview where the world can be explained according to a consistent set of rules and it is assumed that there is an existence that transcends the system such as a God or a constitution (Fig. 4 left). On the contrary, Japanese presupposes a potentially-inconsistent worldview where different rules are accepted for different groups. It is interesting that there is a similar point as in the difference between English and Japanese languages. If thought is determined by language, does it not mean that the Japanese are an appropriate ethnic group to introduce a study of synthesis (*Synthesiology*) to the world?

I shall summarize the prerequisite of natural sciences:

・Analytical methodology can be applied
  – Observation does not interfere with the subject
  – If there is any interference, it can be calculated (including the quantum uncertainty principle)

・Objectivity can be maintained
  – The perspective of the external observer is maintained
  – The consistency of the world can be maintained

**Fig. 3 Perspective of bird.**

Although the perspective of the internal observer is not scientifically desirable, some fields must assume this situation. One must inevitably take internal perspective into account in creating/constructing a system. As will be explained later, in constructing a new system, the steps of first setting specifications, drafting a plan, and then implementing it do not necessarily flow smoothly. The phase of using and evaluating the created system is necessary, and in this case, the researcher is included in the system as a user. In that sense, methodologies for analytic sciences and synthetic sciences are different. Discussion on the synthetic methodology begins by correctly recognizing this point.

The following fields may necessitate synthetic methodology (as will be explained later, this does not imply that analytical methods are unnecessary):

・Complex systems
・System with macro-micro interaction (like economics)
・Multilayered systems (like humans)
・Amorphous systems, which is crystal-like locally, but are uneven globally
・Once-only, non-experimentable phenomena (such as the theory of universe, geology, evolution, history, and archaeology).

The above discussion suggests that not small number of fields necessitate the use of synthetic methodology.

## 4 The loop of synthesis

In general, analysis and synthesis are considered activities that go in opposite directions. Analysis divides the whole into parts, and studies the individual parts and their interrelationships. In contrast, synthesis assembles the whole from parts. This rather simplistic view is based on the image of disassembly and reassembly, but rarely are parts available without a shortage or an excess of them at the start of the synthetic process, that is, in prior to we know what we are assembling. Synthesis must start from the identification of the parts. Moreover, it is extremely difficult to identify the parts from whatever one wishes to synthesize and there is no algorithmic method.

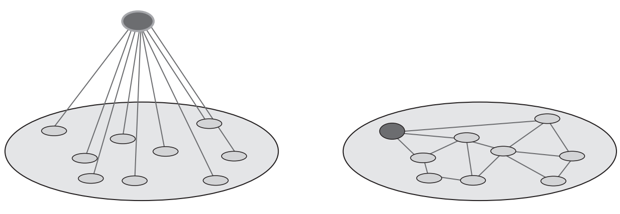

**Fig. 4 External view (left) and internal view (right) of systems.**

We think that the analytical method must be used as part of the synthetic method (Fig. 5). Take for example, architecture. When a requirement is given for a building, a building with functions matching to the requirement can be designed directly in an ideal case, but this is difficult unless the architectural style is standardized. Normally, something that fulfills the specifications is constructed (generated) (this is discussed further in Section 5). This construct may be a model or an actual house, but it is important to actually generate it. By actual generation, details that surpass the given requirement will always be added (specified), and unforeseen interactions with the environment may occur. Therefore it is necessary to analyze the construct and clarify its property. The procedure of analysis is not necessarily fixed and new procedure may be used after their generation. When analytical results are obtained, the necessary feedback is generated after comparison with the original specifications. The specifications may change in this process. The synthetic loop may not end here, and specifications may continue to change and be repeated. This loop is the core of synthetic method.

Notice that the specifications (goals) change within a synthetic loop. In the sense that an analytical procedure can be determined only after the actual construct is generated, analysis and synthesis are not simply activities in opposite directions, but can be considered to be orthogonal to each other.

When formulated as above, the creation of hypothesis in the natural sciences becomes a synthetic loop in the meta-level of theory formation. A hypothesis is generated, and an experiment (or a thought experiment) is designed to investigate the phenomenon that can be deduced from the hypothesis. The methodology for investigation of a hypothesis (i.e. an experiment) is well established in analytical sciences, while the method of evaluation and investigation of the products is not established for the case of synthetic methodology. I conjecture that the only synthetic evaluation methodology is a similar one to evaluation used for story-telling or novels (to be discussed later). In fact, in the evaluation of a hypothesis (which is a result of a meta-level synthesis), the "Ockham's razor" standard may be applied where simplest explanation is selected from multiple hypotheses that can explain the same phenomenon. This is perhaps an example of narrative evaluation.

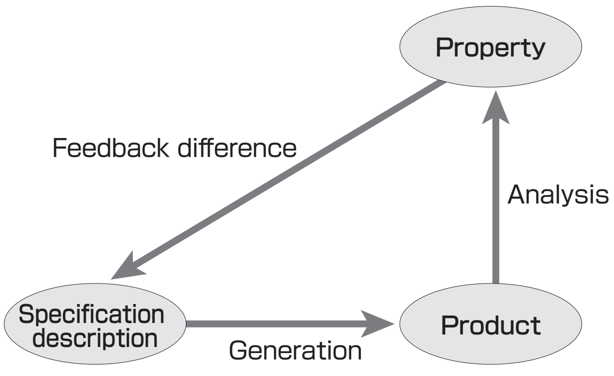


**Fig. 5 Synthetic loop.**

The synthetic loop may roughly correspond to the process of "*Type 2 Basic Research*" as described by Yoshikawa[8], and the aforementioned hypothesis creation corresponds to "abduction."

For example, the derivation of a principle in theoretical research is synthesis but its validity is verified by deductive analysis of its consistency with existing theory and by induction through experiments. For artifacts, this is verified by actual use in society. From this perspective, *Type 1 Basic Research* is totally different from *Type 2 Basic Research*. Considering the logical structures of *Types 1 and 2 researches*, they both include abduction, but the importance of abduction is greater for *Type 2 research* through all stages of the research process. Furthermore, in *Type 1 Basic Research*, the verification process is done by researchers themselves or by other researchers in the same discipline, but in *Type 2 Basic Research*, it is demonstrated in society, which is unrelated to the world in which research is conducted. (Reference [7], p. 6)

Since Yoshikawa considers *Product Realization Research*, he assumes the society is the only place of verification, but for arbitrary synthetic science, it is more suitable to consider the "environment" in general as a place of verification.

## 5 Evolutionary methodology

What is the methodology for "generation" in the synthetic loop? I believe the only possibility is a similar one to evolution. It is a search method commonly called "trial and error." To put it simply, evolution is the repetition of the following process (Fig. 6).

1. Various candidates are generated from existing seeds.
2. Candidates are evaluated, and only good ones are selected.

While the generation of candidates can be achieved mechanically, evaluation is more difficult in general. However, the various possibilities are not just generated randomly. Efficient search methods are necessary and the genetic algorithm is one example. Locally, hill-climb

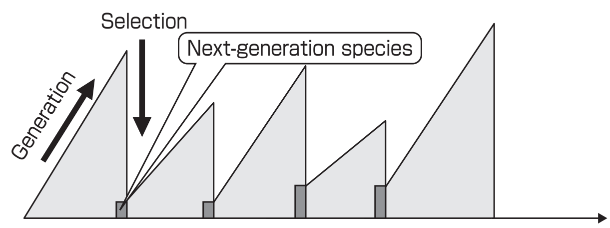


**Fig. 6 Scheme of evolution.**

algorithm or optimization method for parameters of equations may be applicable, but those are limited to areas where analysis of the subject has completed.

Ichikawa[18] sets the following conditions for a system to be an evolutionary system:

・ Existence of self-replication unit (genome) to maintain regularity
・ Existence of a system structure of self-replication units (existence of elements and a system that connects those elements)
・ Possibility for mutation of the system structure
・ Interaction (competition) among replicator systems (for frequency of replication)
・ Existence of external environment

Ichikawa defines the scientific method as follows:

1. Prediction is made by deductive inference from a model that consists of hypothesis and constants.
2. Observation and measurements are planned and conducted to confirm this prediction.
3. A hypothesis is confirmed when facts obtained from observation and prediction match.
4. In case evidence is found that contradicts the prediction (a counterexample) is obtained, the hypothesis is rejected as false. Using the evidence, inductive inference is used to rebuild a new hypothesis. Return to 1.

Ichikawa claims that modern science and technology are comprised of an evolutionary system. This is evidence that evolutionary methodology is one of a synthetic method. On the other hand, it is difficult to argue that this is the only possible methodology. However, there are plenty of circumstantial evidences supporting the claim.

First of all, evolution in nature, or biological evolution, succeeds by employing this method.

Second, *shogi* (Japanese chess) and *go* that have thousands of years of history take this style. Only evolutionary methodology exists in these games, which more number of people who are as smart as or smarter than researchers had studied over the years.

There is no formula for win in *shogi* or *go*. Although certain well-analyzed series of moves are studied as *joseki* (the set sequence), other parts are just emergent or trial and error in form of *sakiyomi* or “reading ahead” where several future developments are evaluated sequentially. Also, explanation of the set sequence is provided in form of *sakiyomi*. In fact, there is no other method other than *sakiyomi*.

The process of generation discussed here is in the same direction as reductionism in analytical science in the sense that it involves generation of details (specific moves in *shogi*) to realize the property of whole (in *shogi*, goal of winning or of capturing the opponent’s pieces). From this perspective, I shall shift discussion to synthetic methodology to generation of a multilayered system.

## 6 Generation of a multilayered system

In this section, I shall elaborate on synthetic methodology with a focus on the generation of a multilayered system. First, I shall define a multilayered system.

It is necessary to understand the various layers listed below to understand the organism called a human.

・ Society
・ Individual
・ Organs
・ Cells
・ Molecules

All these (conceptual) layers must be combined to understand a human. In analytical science, there is a method of explanation by isolating one layer at a time, but there is no methodology of understanding several layers together. It is impossible to understand human society only by molecular biology in a reductionism style. There is an individual law in each layer, and the lower layer is not a disassembly of the upper layer. That is, the existence of multilayer must be accepted as is.

I shall discuss the methodology for addressing the multilayer system. First, taking the analytical method, let us simplify our subject and consider two-layered system. I take as an example, the description of performing music according to Kimura[19] (Fig. 7). In playing music, there are two layers: the layer of the music that one wants to perform and the layer of the actual performance. Three factors enter the two layers.

1. A future noema[Term 1]: plan or the music score one wants to perform
2. A noesis: actual performance, actual notes played
3. A current noema: music conceived as the result of listening to notes played

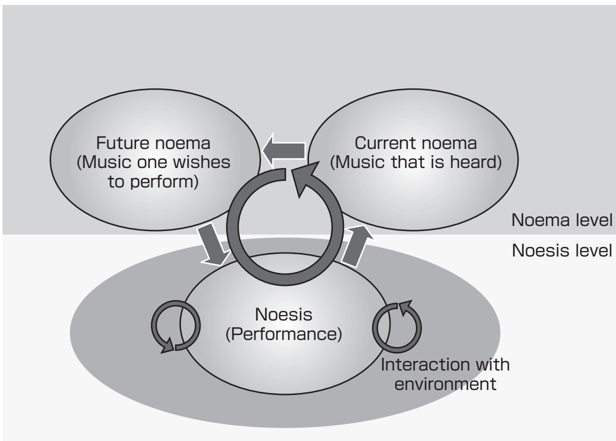


**Fig. 7 Noema and noesis in musical performance.**

Most important here is the interaction of noesis and the environment. In the example of music, temperature and humidity of the day, reverberation of the hall, response of the audience, and many more else are reflected in music. It is important to note that there are factors that cannot be controlled directly by the player. Almost all activities of generation involve such uncontrollable interactions. Traditionally, these were not considered important, but synthesis is very difficult because of the interaction with the environment. In case a company manufactures a product, for example, the user may use it in unexpected manner. Using pocket pager for message communication or explosive dissemination of mobile phones because of their unexpected usage are some examples. However, many in the fine arts actively employ this type of interaction. Bleeding and blotting of ink in shodo (Japanese calligraphy) and firing and ash inclusion in ceramics are good examples.

The product is analyzed after interaction with its environment. One becomes aware of how the music is being played, and the difference with what one actually had in mind is fed back to the next moment of performance. Continuing this loop is the synthetic method of musical performance, and it is a speedy loop with a high frequency. Research is carried out in a longer loop with a larger time constant. However, both loops have fractal structure, and similar loops can be observed when each transition is examined closely.

The reader may have become aware that the loop of noema and noesis has the same form as the aforementioned synthetic loop (Fig. 5). FNS diagram[Term 2] of synthetic methodology[20][21] (Fig. 8) shows this in chronological order.

The meanings of the arrows in Fig. 8 are as follows:

(C1) Action conducted to realize the future noema.

(C1.5) Generated noesis interacts with the environment.

(C2) As a result, a current noema that is different from expected future noema is produced in the upper layer.

(C3) Feedback action to a new future noema. This may include increasing the set of controlled variable and changing plans.

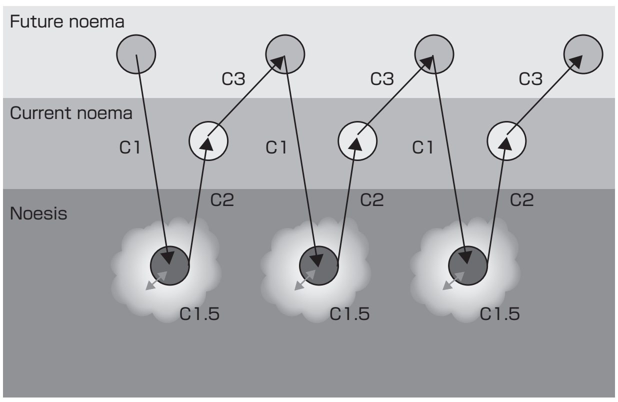


**Fig. 8 FNS diagram of synthetic method.**

The scheme of noema and noesis can be applied to the actions of a scientist engaging in natural science (analytical science) (Fig. 9). When the logic (or hypothesis) exists in the form of a future noema, then the apparatus for experiment is the externalization of the noema set up to justify the hypothesis. When the actual experiment is conducted, interactions with various factors in the environment take place to produce certain phenomenon (corresponding to a musical performance). Feedback is provided to the theory by analyzing the observed phenomenon (correction or justification).

When we extend the formalism to a multilayer system, the FNS expands to multilayer in the noesis level (Fig. 10)[22]. The figure shows three layers, and higher layers are on the left. The item that was an external environmental factor in the lower layer (right side) is internalized in the noesis in the upper layer (left side). That is, the system that consists of noesis (in the center) and other elements (distributed in the environment) on the lower layer (right side) become either the central noesis or one element of the environment in the upper layer (left side). For the example of music, the audience, who was included as part of the environment when seen from the layer of the player, becomes part of the system in the upper layer of the total performance. What is considered one system in the layer of the player is broken down into further subsystems (such as eyes, ears, or hands).

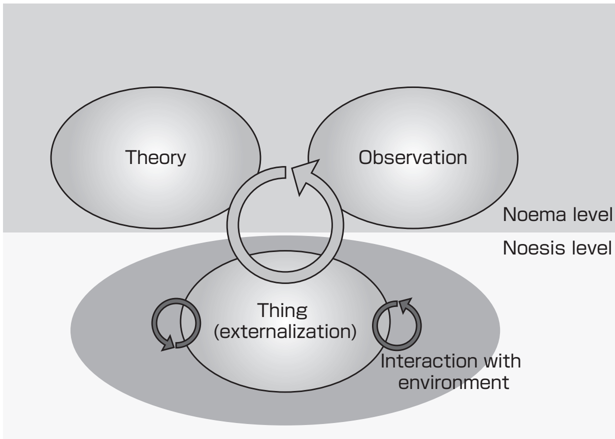


**Fig. 9 Noema and noesis in act of science.**

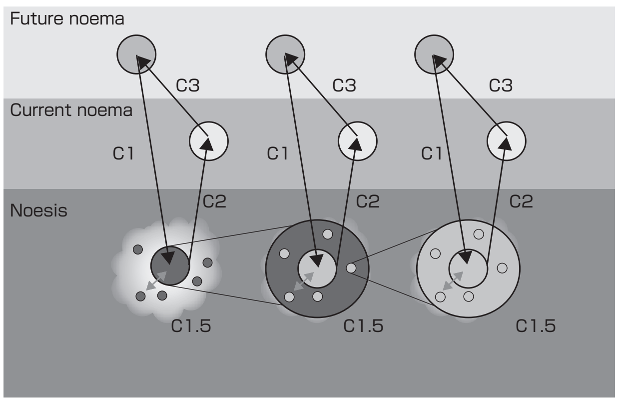


**Fig. 10 FNS diagram for multilayer system.**

In the lower level, noeses are decomposed along "part of" relationship. On the other hand, noemas take on a different description system. For example, individual level noema and cellular level noema form independent systems. Some of the relationship between different layers of noemas may be analyzable. The classic example is that temperature (upper layer) in thermodynamics is the average value of kinetic energy of molecules (lower layer), but it is rare that such relationship is known.

## 7 Narrative

I mentioned the hypothesis that the only method for evaluation or proof of synthesis is narrative methodology.

There is no index for evaluating a narrative objectively. Judgment of good or bad story is personal, and people do not necessarily agree. However, a good novel is accepted by many people and wins many awards. In that sense it may be possible to evaluate synthesis.

Good narratives often have the following conditions:

- There is a strong relationship (causal relationship) among factors of a narrative
- One factor should have relationships with as many other factors as possible (there should be no isolated factor not related to other factors).
- It is better for the relationship between factors to be not too obvious.

Narrative explanation is sometimes used in physics. In fact there are two ways of explaining reflection and refraction (Fig. 11). One uses the law that the angle of incidence and the angle of reflection are equal, and the other is a teleological explanation that light travels via the shortest route from point A to point C. It is the same for refraction, where one can use either the angle of reflection or the shortest time.

The shortest time route cannot be determined unless the goal is known. Therefore, the route cannot be calculated for light itself. That is, the analytical explanation is a method in which time is eliminated and the argument is addressed as a spatial issue, but in a synthetic thinking along time, the laws of angles of reflection and incidence must be employed since they address a local mechanism (in fact, there are finer mechanisms of light as wave, but this will be not be discussed here since the essence remains the same)[23].

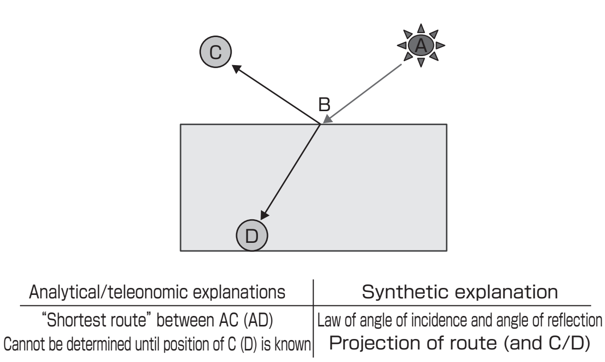


**Fig. 11 Analytical (past) explanation and synthetic (future) projection.**

## 8 Service engineering

The Center for Service Research was established at AIST, and service engineering also uses a synthetic discipline.

In a certain English-Japanese dictionary, there are 23 translations of word "service." This means that 23 examples are introduced because there is no single concept (word) in Japanese corresponding to "service". Therefore, the word "service" in "service engineering" can be interpreted differently by different people. I consider "service" to mean "to use" rather than "doing something free of charge." Also, engineering is a synthetic methodology, the topic of this paper. Therefore, the service engineering is not a discipline of a tertiary industry service, but should be understood as related to a practical application of a synthetic discipline. The process of service engineering can be mapped onto the FNS diagram.

Figure 12 shows the direction of the future research that was summarized in the workshop[24] organized by the Japan Science and Technology Agency. In conventional R&D, the focus has been mostly on manufacturing things (bottom right), but the service part, in which the thing developed is actually used, is important. Continuation of the loop of use, evaluate, create new values if necessary, and then the return to R&D is "*Full Research*" in Yoshikawa's term as I understand it, and synthetic methodology is covered in this diagram. In fact, when Fig. 12 is rotated by 120 degrees to left, it is mapped into the first cycle of FNS.

Peter Drucker foresaw the importance of use (service) in the 1960s, and following statements can be seen in *Age of Discontinuity*[25].

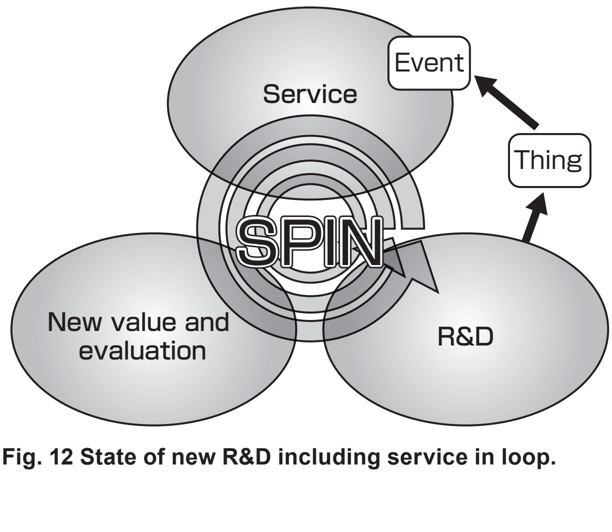


**Fig. 12 State of new R&D including service in loop.**

The search for knowledge, as well as the teaching thereof, has traditionally been dissociated from application. Both have been organized by subject, that is, according to what appeared to be the logic of knowledge itself. The faculties and departments of the university, its degrees, its specializations, indeed the entire organization of higher learning, have been subject-focused. They have been to use the language of the experts on organization, based upon "product," rather than on "market" or "end use." Now we are increasingly organizing knowledge and the search for it around areas of application rather than around the subject areas of disciplines. Interdisciplinary work has grown everywhere.

This is symptom of the shift in the meaning of knowledge from an end in itself to a resource, that is, a means to some result. Knowledge as the central energy of a modern society exists altogether in application and when it is put to work. Work, however, cannot be defined in terms of the disciplines. End results are interdisciplinary of necessity.

## 9 Summary

In the research and development there are many areas where the methodology of the natural sciences cannot be applied. I would like to emphasize this fact to the research community. The role of *Synthesiology* is to cover those realms. I have reviewed the methodology of synthetic disciplines in this article.

I stated that the structure of Japanese that we use, the perspective that is demanded by Japanese language, and thus the Japanese worldview is close to synthetic methodology. I attempted formulation of synthetic methodology.

Finally, I shall summarize the difference of the worldviews.

| Consistent worldview | Potentially-inconsistent worldview |
|---|---|
| **Monotheism** | **Polytheism** |
| **Cartesian dichotomous world** | **Inseparable " 色即是空 (form itself is emptiness)"** |
| **Analytical method = science** | **Synthetic method** |
| **Objectivity (*mono* = thing)** | **Subjectivity (*koto* = event)** |

Formulation of synthetic method is an area where Japan can contribute greatly, and I think this is the major role of *Synthesiology*.

## Terminology

Term1. Terms "noema" and "noesis" were originally conceived by Edmund Husserl, and Kimura uses them with slightly different meaning. Since it is very difficult to explain them simply, please refer to the source, or consider them as mere symbols in this article. I shall present alternative way of reading them, but these are not definitions of the terms. A noema is like a concept or plan. "Specification description" in Fig. 5 is an example of noema. A noesis is actualization of noema. The product of "Generation" in Fig. 5 is an example of a noesis.

Term2. Historically it was Fujii-Nakashima-Suwa diagram. Recently it was renamed Future Noema Synthesis diagram.

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