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Some Issues for Effective Academic-Industrial Joint Works

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Abstract:

Under the globalized economy, international competitiveness is the key factor for the continuation of enterprises. Therefore, industry needs more innovative technologies. Furthermore, it is imperative to develop corporate strategies, manufacturing technologies and advanced products so as to meet the stringent requirements of today's global issues such as the explosion of populations, food and energy shortages and environmental pollution. Since these problems cannot be solved by engineers and natural scientists alone, but should be solved by the introduction of new science which is integrated with cultural and social science too, industry seriously expects academia's collaboration. This paper points out some issues to be solved, and proposes the measures for making effective academic-industrial joint works.

1. Introduction

1.1 Expectations for universities and realities

It is considered necessary to have academic-industrial joint research. Is it carried out effectively, however? Frankly speaking, such research seems to be carried out ineffectively. What are the reasons, then? What can cause them to be carried out effectively as expected? The theme of this paper is to consider what they are. First the author would point out some facts.

According to the questionnaire survey answered by participants at the 1997 Spring Meeting held by The Iron and Steel Institute of Japan, approximately 40% of the respondents from industries answered that universities should provide advice on actual problem solving in industries, and approximately 10% answered that industries should transmit their research needs to universities. Another questionnaire survey conducted at the same time indicates that 83% of university professors and staff think it necessary to have academic-industrial relations. Approximately 60% of them are not satisfied with current relations, of which 50% are not satisfied with the relations because industries are not open-minded or positive about establishing the relations. With regard to the industrial information, 43% of universities want to obtain information on problems in actual manufacturing fields, 21% are interested in user needs, and 34% wants details and plans of research at research institutes[1].

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These surveys disclose the following facts:

- While universities have a strong desire to develop academic-industrial relations, industries do not.
- Universities feel that industries are reluctant in establishing academic-industrial relations.
- Universities want to obtain contemporary industrial information.

The surveys imply that a large gap exists between industries and academic bodies regarding academic-industrial relations, taking it into consideration that 70% of the participants in this meeting are manufacturing department engineers. Why did barely 10% of the industries answer that they want to develop relations with universities and need to give publicity to research needs, whereas 40% expect research and advice on actual field issues.

With regard to the above, a survey conducted within Nippon Steel Corporation in 1993 by the author shows the priority of expectations by universities as follows:

- Highly professional characteristics
- New ideas
- Highly sophisticated research techniques
- Multi-disciplinary functions

Thus, 90% of the respondents expect new concepts and leading principles[2].

If engineers in industries have abandoned cooperation with universities in searching for some guiding philosophy from universities, while suffering about solving the subjects in manufacturing, the problem is so serious. On the other hand it is a somewhat worrying also that approximately 30% of industrial information required by universities is about details of research and the plans. Should not universities have higher level research subjects and plans than those of industries?

The survey results seem to point out a problem in academic-industrial relations, regardless of whether the results are specific to the iron and steel field.

1.2 Necessity for cooperative research

The author had once conducted a survey on inter-firm joint work. Its results showed that 60% of the cases have reasons for cooperative research toward mutual interpolation of knowledge, 20% for reducing the time required for research and development, and 15% for reducing costs or avoiding risks[3].

The funds spent by a company for research and development must be recovered. To recover all the funds spent for researches and investments, the return on investment must be sufficiently large. If the return on investment is about 10% of the total investments including R and D expenditure, the recovery of spent funds is far longer than 20 years; if 20%, the pay back period will be 10 years; if 30%, 7 years; and if 40%, about 5 years. All of these point to the importance of thoroughly performing preliminary and interim assessments of the research, and always keeping in mind the necessity to reduce research time.

The author thinks the reasons Japan's manufacturing industries have been able to achieve global leadership in a short time is as follows:

- Producing a large number of engineers by changing the educational system after World War II
- Realizing operation systems based on voluntary activities of operators
- Establishing close cooperation with consumers

At any rate, they could not afford enough time for many experiences and were allowed only a limited time to rapidly reconfigure manufacturing industries behind those in the rest of the world. All engineers, operators, and consumers had to get together to develop manufacturing technology so as to manufacture high-quality products with fully operating equipments that were constructed at enormous expense.

While time was critical in industry, academics were liable to conduct researches with much universal coverage as possible over a long period of time. As a result, there emerged a disagreement between industry and university. Furthermore, there were a protest movement against industry-university alliance, and times of zero ceiling of a national budget for universities. All of these facts became the roots which hampered favorable industry-university joint work.

However, those in the vanguard of developments are subjected to threats from their followers. Under today's global economic system, international competitiveness is the key to survival of industries. Technology decides which one will win. Technology is not an incremental but must basically be an innovative one. In today's technical fields, some technologies may be part of industrial secrets because there exists corporate competition. This fact understandably tends to make industries close-minded. Honestly speaking, however, the development of truly innovative technology all by industries alone has been quite difficult. As already mentioned, this is exactly the background that urges universities to produce new concepts and leading principles. In other words, industries have been looking for effective cooperative research. What mismatches them then, despite these facts?

2. Hierarchical Structure of Research

2.1 What traps modern science research

As the reader knows, the word "technology" is composed of "techne" and "logy" which mean art and study in Greek. Technology, as it implies, originally meant a measure to make something belonging to an individual. The word "science" originated from "knowledge" in Latin. The later meaning of systematically classifying things was somehow applied during translation of English "science" into Japanese "kagaku".

According to the *Discours de la Methode* by Descarte who is said to have significantly influenced modern scientific methodology, science demands rechecking all aspects of complete phenomena without leaving anything that can be guaranteed, as no item is left unexamined[4]. This makes us think that science starts from classifying and really makes us respect the translator for his excellent view. However, considering this carefully, we notice that manufacturing process is synthesis, while science is rather analysis, and that their vectors differ completely.

So-called scientific research at today's universities has been classified into really small categories, which does not make it successful to apply the results of such research to technology by synthesizing each individual theory. The author calls this phenomenon the trap of Descarte and thinks that one factor preventing cooperation between industries and academia seems to reside in a large difference between analytic research by universities and synthetic research by industries.

There is another big misunderstanding. Natural science is to investigate dominant principles of all kinds of natural phenomena; thus, technology was generated by applying discovered principles. In other words, science does not originally aim at applications but is rendered to genuinely pursue principles. However, science would not need such a serious treatment if it were started in order to know, as previously mentioned. As a matter of fact, in the U.S. and U.K., every study has the word science added, e.g. Economic Science, Social Science, or Political Science.

The notion of science being superordinate and technology subordinate seems prevalent among people and they still seem to believe it. If such is the case, how can they understand, for example, that thermodynamics originated from research on how to improve steam engine efficiency and that radiation theory originated from another on how to measure blast furnace temperatures? In other words, why is an action to pursue a theory with an objective purpose not called science?

The notion of superordinate science and subordinate technology must be abandoned when we consider the facts that many Japanese manufacturing industries have established manufacturing technologies by theorizing experiences in an extremely short time and that Japan produced the notion of science technology which can even be said to exist only in Japan. It is especially necessary to notice the fact that industrial-academic work can hardly be effective if fundamental scientific research is conducted by universities and the rest, including applied research, by industries.

2.2 Emergence of new research methods

Engineering researches have historically made great achievements and contributions to the development of industry by theorizing manufacturing experiences and mysterious phenomena, and by forming engineering fields inherently related to individual industries by transforming laws and rules into technologies. In short, industry and universities traditionally built a desired relationship by interchanging discovery of laws and rules by universities with acquisition of experience by industry. In addition to the difference in the sense of time between industry and universities, mentioned in the foregoing section, another problem which estranges the one form the other has arisen.

With increased complexities of various subjects for industry, it has become difficult to respond to these problems only by means of theorization. For these problems, a method in which modeling is first conducted on the basis of a low or a rule, followed by the pursuance of the discovery of a program to solve the model has been introduced[5].

In this method, it is necessary to obtain an answer which is well applicable to a field phenomenon, regardless of a theoretic model, an experiment model, or an empirical model. A data base required to solve such a model can be not only physical or chemical constants but also those which are obtained by experiment or experience. Industries will depend on this method considerably to the extent that it is practical, regardless of whether a model can be verified theoretically or not. Further, they do not have to depend on universities any more if a model or data base can be obtained through actual field work.

This method is quite a useful means for researchers and engineers to solve problems in industries by themselves, but is not commonly applicable and powerful with regard to changes in external conditions, thereby requiring theoretic proof[6]. A fact is more powerful than anything in the technical world. The factual power often makes the truth vague. Paradoxically speaking, do not allow a fact to deceive you. What needs to be emphasized is that wholesome industrial-academic relations may be established by sharply pointing out errors or misunderstandings held by universities regarding what industries insist are facts.

2.3 Corruption of classical research hierarchy

As shown in **Fig. 1**, there is a decisive defect in conducting research according to the so-called Linear Model as in the sequence of science, fundamental research, applied research, development research, and commercialization, which derived from the superordinate-science-subordinate-technology notion.

In achieving some objective, if cooperative research is carried out according to a hierarchy described above, a definite protocol (conditions on receipt and delivery) must exist among hierarchies such as foundation, application and development. All those engaging in research must understand an objective clearly and conduct committed research for which each researcher promises what will be output and when it will be ready. However, it is almost impossible to set such a protocol if each researcher belongs to a different research organization, since research qualities vary according to fundamentals or commercialization. Further, even if a plan has been set, an objective may often be changed with time, which will consequently change all receipt and delivery plans, from fundamentals to commercialization. In other words, hierarchy-type research considerably lacks in flexibility for research with an objective.

The interactive model, as shown in **Fig. 2**, is proposed in order to compensate for the above fault.

In this case, it is essential that a high-quality project manager should exist. However, it will require a considerable amount of time to persuade researchers who do not understand or accept the reason to change the research plan. That is, conducting cooperative research on a mutually related model can hardly be successful unless partners engaging in the research are assured of a fair amount of benefit based on achievement of an objective in a specified duration. In fact, the survey performed by the author verifies that among 20 failures 7 did not have a definite objective or provide a fair amount of benefit, 6 lacked in mutual understandings, and 7 spent over three years on cooperative research. These cases prove the importance of setting a definite common objective, a fair benefit, and observing duration[3].

Recently, as shown in **Fig. 3**, so-called object-oriented joint research has been conducted on projects for which an objective cannot be clearly set from the beginning. In this research, an objective is vaguely set to perform a project. Then, if a result that differs from what the researchers expected is obtained, the contents of the project are changed to perform it again to check another result which will be obtained, thereby achieving what the researchers expected. This method facilitates the gradual quantifying of an objective which initially was vague and furthers mutual understanding between partners, but does not assure success if the pursued benefit differs between the partners. The issue discussed here, then, is a benefit or a research value which will be obtained through the research.

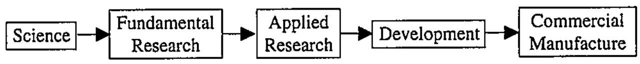

Fig. 1 Linear model

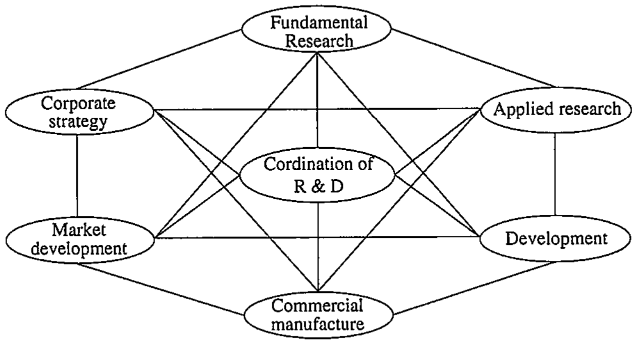

Fig. 2 Interactive model

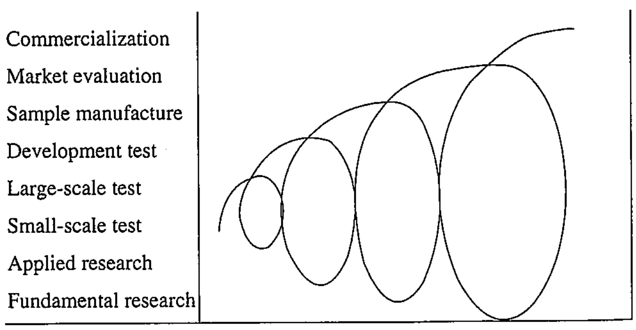

Fig. 3 Object-oriented model

3. Key to Problem Solution

3.1 Research value

Evaluating research is an issue which has recently been discussed at universities and national research organizations. For example, at universities, self-examination or self-evaluation is required, and evaluations are strictly specified in the "Law of the Basic Plans for Science and Technology". It may be a matter of course to have accountability explaining to nations the research which is supported by national tax. Equally important, what the measures are applied when assessing research values? It is difficult to evaluate research unless this measure is defined.

Here, research values are classified into intellectual value, social value, and economic value, however they may be understood variously. Among these items, the economic value may be quantified most easily. As mentioned previously, industries evaluate investment recovery relative to research costs. The difficulty is to evaluate it when future prospects are vague at the initial research stage or if there is no definite party or person who will receive benefits from the research. Research is not what guarantees success from the beginning. As time passes, it may become obvious whether research will succeed or not and who are its beneficiaries. Therefore, industries regard prior and intermediate evaluations as important.

Although both the intellectual value and the social value of a research conducted by a company are assessed when a report is presented at a conference, or the like, the researches implemented by companies are mostly commitment researches which promise results, and their value is assessed by their economic value.

In contrast, university research may be valuated by intellectual values. While there exists such a measure in economic values, does an objective measure exist in intellectual values? Engineering research originally plays a role in giving benefits to society or people, which can be called mission-conscious research. In other words, intellectual values in engineering research at universities can be set with a measure if future possibilities can be objectively evaluated to provide benefits for people, society, or industries.

The problem is whether or not research is conducted with such consciousness at universities and whether there exists a system to objectively evaluate such research. Stated positively, the problem lies in whether universities can conduct research considering conversion of intellectual values into social and economic ones. This question is discussed in the next section.

3.2 Serendipity and telesis

It is often said that a great discovery or an invention was coincidentally achieved as a result of pursuing some mysterious phenomenon encountered during some kind of research. This is what is commonly called a serendipitous discovery. Industries experience such discoveries, and there are many successful examples. Yet, depending on all research for coincidence or luck spoils the research itself and it is unable to manage them. Therefore, much research sets up a definite objective and conducts the research according to the plan. This is called telesis research. If some interesting data is obtained in the research process, its researcher is allowed to pursue it so long as the planned research is not delayed. According to the author's experience, it is important for industrial research to give researchers such freedom.

East or West, many examples of great discoveries in universities prove that such discoveries were coincidentally achieved by freely pursuing the result of experiments. Were those discoveries developed into great inventions by discoverers as well? Considering the past examples and facts, in many cases discoverers and inventors are different persons, which makes it difficult for the author to give an appropriate example.

How can intellectual values be converted into economic values as described in the previous section, if the discovery is determined as creating intellectual values and the invention as creating economic values? To make this conversion possible, a coincidental discovery needs to be combined with an appropriate objective and to be rendered to an application through planned research, i.e. a serendipitous discovery needs to be switched to telesis research. This is often referred to as "matching seeds with needs", which cannot be easily achieved, however.

3.3 Seeds and needs

Matching seeds with needs can exactly be compared to the relationship between a seller and a buyer at a market. What we have to note carefully is that there are two kinds of matching of seeds with needs. In one case something required was exactly found and in the other seeds are or could be either a part or a partial element required to commercialize something.

In the former case the seller and the buyer may amicably contract with each other, which can seldom happen. In the latter, there may possibly be various cases depending on how many elements of needs are being supplied by seeds. For example, many cases show that research and development succeed based on information obtained in academic meetings. During some difficulties, the author has an experience of solving the problem thanks to a clue given in an academic presentation of a field foreign to the author. In other words, it is not always adequate to criticize usage of disclosed information, because the user decides how to use it.

We often hear a criticism that industries collect only information from universities without rewarding or responding to what they have received. It is a fact, however unpleasant to hear. To get rid of such an ill practice, seeds should be extended to the primary application, while industries should be more ethical. It is necessary to show seeds can be used in various ways and to stimulate imagination for needs by conducting research for ultimate applications. Otherwise, precious intellectual values will be evaluated unfairly low. Due to this, universities must make appropriate market research or analyze needs and seek cooperative relations with people in many different fields. Universities must be quite advantageous to construct such cooperative relations because they have many disciplines. Readers of this paper are requested to remember that they function as a collective body of different specialties in the survey with questionnaires regarding expectations from universities. Thus, if seeds can be converted into such that a certain application is imagined, cooperative research will be carried out quite easily.

Normally in cooperative research between industries, there is a general principle of sharing both research costs and obtained results with partners. In the author's experience in the U.S., tangible and intangible assets such as researchers' intellectual or proprietary rights are often valued and employed as part of the investment capital. In this case, data required to value them are prepared and hardly any example is like one in which seeds are added with subjective evaluations and, specialists who can make market research or cost analyses are hired to prepare data that permits discussions. As a matter of fact, they are quite good at making presentations and team up with different professors to successfully explain the course of solving a problem. This fact seems to be the reason Japanese industries ask American universities to conducting research, not Japanese ones.

The seeds selective model as shown in **Fig. 4** compensates for

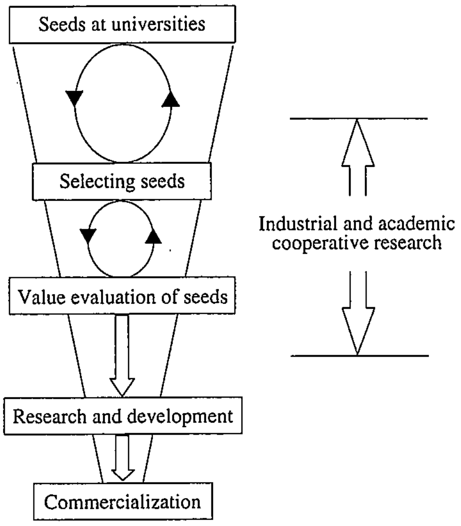

Fig. 4 Seeds selective model

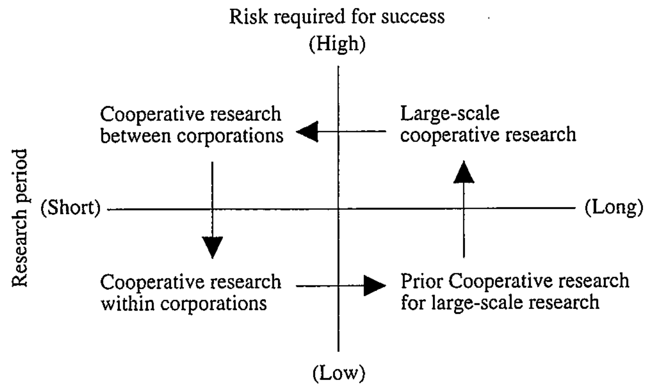

Fig. 5 Form of cooperative research

the above shortcoming. This model does not directly concern seeds to needs, but is used for research and development that is related to applications for which industries and academia cooperatively select seeds or reanalyze needs so as to make them conform to each other. Anyway, it should be emphasized that precious intellectual assets will be a dead stock unless intellectual values are wisely switched to economic ones.

4. Conclusion

As have been described throughout this paper, the following are the premises for succeeding in cooperative research:

- Clearly determining the objectives for cooperative research
- Mutual understanding of other partners' technology
- Assuring fair benefits between partners

In other words, partners must be mutually responsible and conduct their cooperative research as destiny sharers. Unless this is recognized, cooperative research makes no sense. Is cooperative research by industry and academia possible under such conditions?

To make this possible, what we want universities to do first is to understand industries' needs, have the desire to wonder whether certain products or processes can be realized or even guess what exists behind the needs, and prepare scenarios to achieve them. In other words, instead of waiting for industries to come to universities with some research themes, universities should propose themes to industries. What we want industries to do is to cooperate more open-mindedly with universities in such efforts.

As shown in **Fig. 5**, there are many forms of cooperative research. Cooperative research can be conducted with related departments in an industry if it requires only a small risk for success and the research period is short. Cooperating industries can conduct another kind of research if it is highly risky but can shorten its research period and share the risk through cooperation. In the case of a large-scale cooperative research that is likely to be really fruitful if successful, starting such research immediately without prior careful evaluation would easily make the partners suspicious of each other about whether or not to continue it, as time passes. This kind of large-scale research is quite suitable to industrial-academic cooperation, and requires prior cooperative research to lead to success or a scenario prepared by both parties. Such prior cooperative research would dispel any mutual suspicion and generate a sense of solidarity as destiny sharers.

The fundamentals of academic research may lie in creating intellectual values. If stress is put on the pursuit of economic values, academic research is not different from research conducted by industries. Therefore, the transition from intellectual values to economic values is an important hurdle to overcome in industrial-academic cooperation. History tells us that certain discoveries at Japanese universities were commercialized in foreign countries. This should be a matter of regret for Japan's business people. So, an important future issue for both universities and industries to consider together is how to doggedly pursue subjects which are unexposed for a long time but considerably effective.

In scientific research, it is said, unless the problems of the existence and stabilization of a solution are discussed, then none of them can be scientific research. In the world of technology, however, apart from the scientific credibility of technology, the adaptability to reality has constituted a criterion, and this concept has contributed to the promotion of technological progress. Various problems considered as technological barriers today may not be solved unless we return to the basics and reconsider what should be done. Further, there have been problems on the borders of natural and social sciences and art, where the problems are caused by factors which cannot be solved by technology based on academic research and which do not belong to natural science, for example, changes to people's desires or social existence, as well as regional or international relations. To cope with these problems, cooperative research by industry and academia must be carried out aggressively, with industry-academia relations being scrutinized like never before. The author hopes that this paper can be of some reference for those engaged in such endeavors.

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