Column 1-3

Tsukuba Innovation Arena

The Tsukuba Innovation Arena (TIA) was established in 2009 with the aim of creating new industries by securing a strong competitiveness that would bring nanotechnology innovation to Japan's industrial sector. Through open innovation, TIA has been promoting R&D projects that are expected to respond to the needs of society and is expected to be used in society. These projects include the Cabinet Office's Funding Program for World-Leading Innovative R&D on Science and Technology, METI and NEDO's[1] project, and MEXT's programs. The total amount of the projects up through FY 2012 had reached 76.25 billion yen (the mid-term target of the first period from 2010 to 2014 is 100 billion yen in total).

The "Innovative Silicon Carbide (SiC) Power Electronics Technology toward Low-Carbon Society" project went through basic research, applied research and trial manufacture, resulting in the commercialization of modules such as inverters. This was the first research project conducted at TIA whose outcome was commercialized.

Carbon nanotubes have many remarkable features. However, since mass production of them is difficult, they are expensive. Thus, carbon nanotubes are called dream materials, and their practical application has not made progress. In the "Demonstration for Mass Production of Carbon Nanotubes" project, researchers have developed a technique for producing carbon nanotubes at 1/10 to 1/100 of the previous cost and have distributed their samples to companies in various places at actual cost. Moreover, in the "Development of Innovative Carbon Nanotube Composite Materials for a Low Carbon Emission" project, researchers have developed their applications and have distributed samples of a composite material, striving to connect them to practical application. At that time, they not only distributed samples, but also supported their practical application by offering necessary technical information. At the same time, they got feedback, such as demands for needed functions, from the companies that would put them to practical use. They then used the information to develop carbon nanotubes that would meet those needs.

In any case, the project was carried out by members consisting of multiple universities, companies and public research institutions. Three years after the establishment of TIA, the total number of cooperative companies has reached 128 (the mid-term target: a total of 300 in 2014), the total number of the projects using TIA center has reached 26 (the mid-term target: a total of 30 in 2014)), and the number of external researchers per year has reached 832 people (the mid-term target: 1000 people per year in 2014). Thus, a strong system of industry-university-government cooperation has been established, and the practice of open innovation has made significant progress.

As for the operating funds, public funds accounted for more than 90% at first, but they were less than 85% in 2012, which indicates the strong commitment of private companies. In 2012, the High Energy Accelerator Research Organization joined the following original core institutions: the National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba University and the National Institute for Materials Science (NIMS). In addition, Tsukuba Power Electronics Constellations, a collaborative research team using private-sector expertise and funds, has gone into full-scale operation, expanding the scope of R&D.

(3) Examples of activities in other countries

In the dramatically changing world where situations involving various kinds of global challenges arise, other countries also are conducting various activities in order to create innovation based on the results of research. Here, we examine some of the activities that will open up new vistas for society's future. Then, we introduce the activities of the European Technology Platform and examine some examples of industry-university-government cooperation at Stanford University in the U.S.

1) Examination of long-term visions in Western countries

In Western countries, some public institutions with an eye toward the future examine the long-term visions of society in order to predict future needs and to use them for making policies.

1 New Energy and Industrial Technology Development Organization

With "the facing Europe" as the theme, the European Commission conducts a project called Forward Looking Activities designed to share visions and work out measures. Since the 1970s, the Organization for Economic Co-operation and Development (OECD) has conducted activities intended to warn the secretary-general and other decision makers inside the organization, and within the member nations, about new challenges. In 1990, the OECD started the International Futures Programme in an effort to present "what is needed now" from a long-term perspective. So far, it has carried out projects closely related to S&T, such as "Space Economy," "Review of Risk Management Policies" and "Bioeconomy to 2030." To be selected as a project, a subject must have a vision of the future, never have been selected before, and the one that require cross-organizational activities.

In the U.S., the National Intelligence Council (NIC) published a report titled "Global Trends 2030: Alternative Worlds" in December 2012. The report described the food-supply problem, the energy-supply problem, the graying population, the increasing middle classes of emerging countries, and the economic development of these countries. As a technology that will have a huge impact on the future, the report highlighted the following four areas: IT technology, new manufacturing technologies (3D printers, robots, etc.) and atomization of the manufacturing process, technology related to the security of vital resources, and health-related technology. It also mentioned the creation of values based on S&T.

In the U.K., the Government Office for Science, part of the Department for Business, Innovation and Skills, carries out activities called Foresight Projects, which are intended to support the policy-making process of the government by providing an understandings of, and prospects for, challenges the U.K. society may face in the future. The project studies subjects in various fields, such as "the future of industrial production," "the future of computer transaction in the financial market," "land use" and "health problems." These subjects are determined by the Government's Chief Scientific Adviser based on proposals made by the government agencies, some 80 universities and other institutions and the persons concerned. Selected subjects are investigated by the Government's Chief Scientific Adviser, workers for the Foresight Project, with other core experts and stakeholders attending (a total of 200 to 300 people). The results are then put together in a report about the future visions and policies are based on the R&D trends of each subject in order to support government decisions.

2) European Technology Platforms

European Technology Platforms (ETPs) are industry-led, bottom-up forums bringing together a wide range of stakeholders, such as public research institutions, public agencies, financial institutions and policymakers. Their aims are to suggest a priority agenda that each research field should address as a whole for the EU's growth, enhanced competitiveness and sustainability, and it aims to define medium- to long-term Strategic Research Agendas (SRA). Naturally, SRAs are widely referred to during the definition process of Working Programmes for the Seventh Framework Programme for Research (FP7) and other EU's R&D programs. Starting with the setup of a platform in the transportation field in the early 2000s, as of 2013, 36 ETPs are operating in five fields, including energy, ICT and transportation. Their forms range from a loosely connected group to one that has corporate status and collects participation fees, but they have a common character trait in that, in principle, stakeholders, especially the industry operate the forum on their own. Users and consumers, such as NPOs and citizen's groups, can also participate in ETPs, which allows various stakeholders to prevent consensus-building processes from overlapping and allows the sharing of their visions. There are regional technology platforms that correspond to ETPs in many countries and regions.

If an ETP reaches a stage where, if the whole or part of the SRA should be carried out on an ambitious scale by using a large amount of R&D funds invested by the government and private sector, that ETP may lead the R&D as a Joint Technology Initiative (JTI) under FP7. JTI is a legal entity established under Article 187 of the Treaty on the Functioning of the European Union. The European Union is deeply committed to its decision making, unlike ETP.

3) Center for Integrated Systems at Stanford University

The Center for Integrated Systems at Stanford University (CIS), established by the faculty members of Stanford University[1] in 1980, is one of the most important industry-academia cooperation centers in the U.S. in the fields of semiconductors, nanotechnology and computer science. The center was funded by a consortium for the manufacturing technology of semiconductors (SEMATECH[2]) when it was established.

CIS collects funds from its partner companies, and more than 70 faculty members conduct research with Ph.D. students. Currently, 17 partner companies inside and outside the U.S. are Full Members that pay $150,000 per year while other partner companies provide a smaller amount of funds as Associate Members. Researchers at the university interact with those at partner companies, and they conduct research that meets the needs of the industrial sector together with graduate students. This industry-university-government cooperation allows the university to collect research funds and also provides graduate students with employment assistance. The partner companies enjoy the benefits of conducting the most advanced research available by collaborating with excellent students and utilizing the human networks of the university.

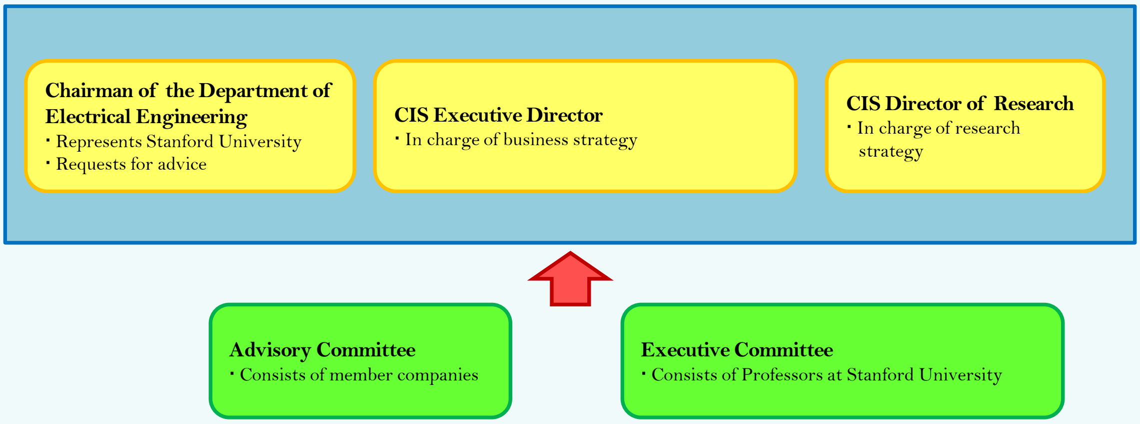
CIS is also one of the bases of the Ultra-Fine Nano-Machining and Molding Research Support Network (NNIN[3]), which is promoted by NSF. CIS receives research funds from NSF, separately from corporate funds. One of CIS's features as an organization is that it not only consists of the researchers in the fields CIS deals with, but also includes researchers specializing in technology management who are engaged in the decision making (Figure 1-2-30).

1 John Young, ex-chairman of Hewlett-Packard, who later engaged in drawing up the "Young Report (Global Competition - The New Reality -)" participated in the establishment.

2 Semiconductor Manufacturing Technology

3 National Nanotechnology Infrastructure Network

Figure 1-2-30 / Decision Making of CIS at Stanford University



Source: Created by MEXT based on the research data produced by the Tsukuba Innovation Arena Promotion Headquarters and the website of CIS at Stanford University

Column 1-4

Platform Strategy

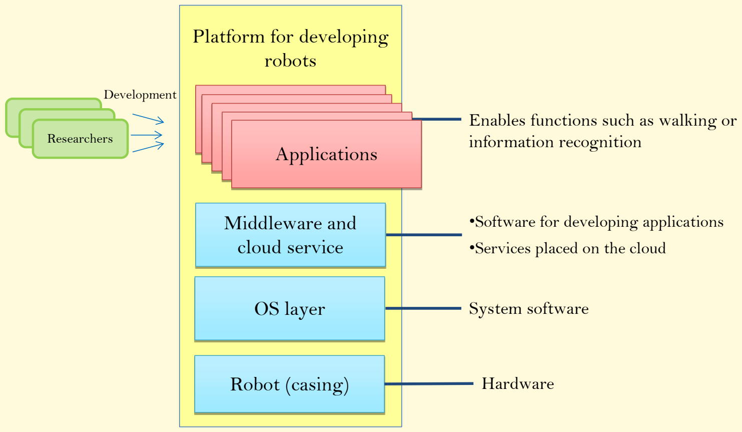
One of the keywords for a new international competition brought about by IT technology is platform strategy. The term, platform, is used not only as the raised flat area at a train station but also in various senses, as a rostrum or a place for discussion. In IT-related fields, it is used to refer to the basic environment where a computer, including an operation system and hardware, is operated.

Take a robot, for example, which can be regarded as a platform including the OS layer, middleware (software for application development), services placed on the cloud and their applications, and the casing of the robot (hardware) operated by the applications.

If researchers developed the casing of a robot and middleware and then distributed or sold them to many research institutions, they could create an environment where the institutions would develop application software that operates on the research platform. Researchers at the institutions would use the research platform for their research. They could concentrate on creating applications to realize various functions without building the casing. In addition, they could establish a community for researchers who would conduct research using the robot casing and share information to accelerate research.

If many researchers participated in the research using this robot research platform, the builder of the platform would be able to make a profit from the increased number of users.

In addition, if the robot occupied a significant share of the market, the middleware and the robot casing could be what is called a *de facto* standard. Moreover, if they not only provided the robot casing but also built a system to use the applications for various uses that need control, they would capture a broader market and would be able to define the architecture of both software and hardware over a long period. For this reason, building a platform and providing an infrastructure that can respond to various uses is a strategy that would create large, long-term profits.



Open platform for developing robots

Source Created by MEXT based on "Robotics Technology and Open Innovation - Robot-OS (ROS) Strategy and Direction of Robot Technology Development in Japan -" Narita Masahiko et al. 2012, Intellectual Asset-Based Management Endorsed Chair of the University of Tokyo, Discussion Paper Series # 27

(4) Activities for developing research environments that allow creativity and originality to be fully demonstrated

The following issues were cited in Chapter 2, Section 1, 2, (1) regarding development of research environments that allow creativity and originality to be fully demonstrated.

· Research environments that allow for the independence of young researchers

· Treatment based on ability

· Integration and exchanges among different disciplines and organizations

· Research environments that allow researchers to concentrate on research

Here, we examine some of the activities currently performed as a response to these issues and the future direction of these activities.

1) Research environments that allow young researchers to display their abilities independently

Regarding young researchers, the Third Basic Plan pointed out that postdocs' career paths were unclear. Measures to support the independence of young researchers have been taken since then, but they were insufficient. Thus, the 4th Basic Plan also included the policy to increase the number of posts for young researchers, stating that "In order to provide young researchers with independence and with opportunities to play an active role, increasing posts for young researchers is needed."

The Council for Science and Technology (CST) formulated the "Basic Policy to Drastically Strengthen R&D Capacity in Japan" in April 2013. It stated a plan to work out concrete measures for young researchers, including the "Thorough implementation of the objectives in the 2005 Amended School Education Law (enforced in 2007)[1], which was enacted in order to appoint excellent young researchers, who are the driving force for university research and to help them become independent leaders as soon as possible, according to the global standard model," which includes the "Promotion of funding to facilitate the 'Labor to Leader' policy that allows excellent young, female and foreign researchers to lead research on their own, instead of being used as the work force," and the "Promotion of activities for developing the various career paths of graduate students and young researchers."

The Science Council of Japan (SCJ) made a suggestion regarding "How the Evaluation System should be" in October 2012. It suggested the following measures: the establishment of an evaluation method to promote challenging research for the evaluation of young researchers; the active evaluation of activities to support young researchers for the evaluation of research subjects; the evaluation of research environments and training; and supporting measures for young researchers for the evaluation of research institutions. The report emphasized the importance of using evaluations to encourage young researchers to try new areas of study. All of these documents pointed out the need to utilize the abilities of highly motivated young researchers.

As one of the measures to support the independence of young researchers, since 2006, MEXT has started a project to introduce the Tenure Track System to universities. The project provides support for organizations that promote a system to allow young researchers to gain experience as independent researchers. So far, 815 researchers in 51 organizations have received support (as of March 2012). It is hoped that the project will expand and take root after going through an evaluation of its effectiveness.

In order to promote creative research conducted from a long-term perspective, and by young researchers in particular, the CST's suggestion, mentioned above, said "For Japan to lead the world, it is necessary to help young researchers become independent, not isolated, as soon as possible with the proper support of research institutions, and it is necessary to develop an environment that allows them to try high-risk research and devote themselves to research. It is also necessary to secure research assistants who have advanced expertise." Grants-in-Aid provide a competitive fund for young researchers—Grant-in-Aid for Young Scientists (A) (research period: 2 to 4 years, total amount applied: 5 million yen to 30 million yen). This program particularly supports excellent young researchers so that they can fully carry out their research independently.

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1 In view of the vitalization of educational study and acceptance in the world, the system regarding assistant professors and assistants was reviewed. The assistant professor system was abolished and the "associate professor" system was established. A new position of "assistant professor" was established for part of the assistants who mainly conduct educational studies.

2) Creating research environments where treatment based on outputs makes researchers active.

The seniority system has been the primary method of wage distribution in Japan. However, the "Basic Policy to Drastically Strengthen R&D Capacity in Japan," mentioned above, has revealed its policy about how treatment should be based on evaluation, stating that "Based on the new ideas for evaluation, the treatment and fund allocations for researchers who receive a high rating should be reflected in the evaluation. For example, an evaluation system based on giving positive points in all the categories should be introduced." Preparing a proper treatment system for researchers is also needed to improve the circulation of ideas on an international level, and it will be discussed in Chapter 2, Section 1, 3. To meet these needs, the Basic Policy stated, "Securing and fostering excellent researchers from overseas as well as from within Japan is necessary in order to support global standards. This can be accomplished by changing the seniority-based pay system; for example, by promoting the introduction of the annual-salary system." As part of the national university reform, MEXT added to the agenda the need to reform the governance of personnel affairs and payroll systems in order to get the best out of excellent young and foreign researchers.

3) Cross-disciplinary exchanges to provide intellectual stimulation and to create new ideas

In order to increase the mobility of personnel in Japan and to allow researchers from diverse backgrounds to interact with each other, some possible measures include preparing experimental open spaces that allow researchers belonging to different laboratories or groups to mingle routinely, and promoting the shared use of equipment in research institutions. The suggestion mentioned above stated, "It is necessary to develop a system to allow researchers to go beyond the borders between universities and to jointly conduct research, such as by establishing inter-university research institutes and a joint usage and research system. Promoting collaboration among universities and public research institutions is also needed. In this way, integrating the activities of multiple researchers having different research methods and different views on research subjects is essential to opening pathways to create new disciplines and to solve social challenges."

The 2012 NISTEP Expert Survey on Japanese S&T and Innovation System asked researchers in various fields about which S&T fields should actively advance integration and collaboration over the next five to ten years. Many respondents answered that collaboration between disciplines relatively close to each other, such as medicine, biology and the life sciences, was needed. However, some pointed out the need for collaboration between fields, especially collaboration between significantly different fields, such as sociology and civil engineering, or psychology and mathematics. Measures to promote these interdisciplinary collaborations will become important in the future.

In addition, CST's Committee on Human Resources pointed out the importance of having a team in which a wide variety of individuals come together to create innovation while "Aiming to foster talented personnel who can lead a knowledge-based society and promote their activities." Then, the report stated, "In order to become an excellent worker who can play a key role in a team, one needs to experience different organizations and cultures when he or she is young and needs to acquire knowledge and abilities so as to flexibly introduce diverse points of view and ideas. Academia will be vitalized only when researchers with a wide range of experiences vie with each other. It is thus necessary to ensure the mobility of researchers, not only inside academia but also outside academia, and to activate the movement of personnel."

4) Research environments that allow researchers to concentrate on research

In the suggestion mentioned above, CST presents the view that research assistants and engineers are indispensable for producing excellent research results. The suggestion particularly points out the importance of training and securing university research administrators[1], who play a key role in research projects or research support systems, and in establishing those roles as stable jobs. In addition, the Basic Policy to Drastically Strengthen R&D Capacity in Japan also states, "University research administrators who have a high level of expertise— enough to jointly conduct research with other researchers— are indispensable."

The project to develop the university research administrator system started on a full scale in FY 2011. According to the 2012 NISTEP Expert Survey on Japanese S&T and Innovation System, respondents in university consider the training and securing of university research administrators are insufficient in the current stage. Thus, the system should be improved.

In order to set aside the time for researchers to concentrate on research, the institutional design has been reviewed to help reduce the amount of researchers' non-research duties. The Funding Program for World-Leading Innovative R&D (FIRST) on Science and Technology, which received a FY 2009 supplementary budget allocation, is the first research fund to be established as a foundation. In FY 2011, part of the Grants-in-Aid also was turned into a foundation. As a result, researchers can use the research fund according to the progress of their research without being severely restricted by the funds management of each fiscal year. According to the 2012 NISTEP Expert Survey on Japanese S&T and Innovation System, researchers rated the reform of grant system highly, as it facilitated the smooth progress of research and reduced the burden of administrative work. In addition to establishing the foundation for research funds, FIRST established the "research support organization" system to provide support for researchers so that they can concentrate on their research. Unlike usual research fund systems, the research support organization is selected based on the requests made by leading researchers. If there is an organization that is capable of providing researchers with more efficient and effective support than the institution they belong to, they can ask the organization for support. Such efforts to reduce the amount of researchers' non-research duties by reforming the design of administrative system should also be applied to various other systems.

5) Improvement of systems and the development of attractive R&D centers where researchers gather from all over the world

As we have pointed out so far, in order to provide creative and original R&D environments, we should first develop environments that allow young researchers to display their abilities to the fullest and then ensure conditions that allow them to concentrate on their research. On the basis of this, the proper treatment for motivating researchers and the promotion of research exchanges to provide intellectual stimulation are important. In a policy speech, Prime Minister Abe pointed out the need to develop research environments in Japan where distinguished professors and excellent students gather from all

1 Personnel who are engaged in supporting such duties as vitalizing the research activities of researchers and enhancing R&D management

over the world, saying, "We will create the world's most innovation-friendly country." Here we describe some of those measures for building world-class R&D centers in Japan so as to create such research environments.

In FY 2007, MEXT started the World Premier International Research Center Initiative (WPI), a pioneering measure aimed to establish international research centers. This program promotes the development of research centers that will attract leading researchers from all over the world and which can boast excellent research environments and a high level of research. Centers are selected under the condition that more than 30% of their researchers will be foreigners at any given time and that the center will secure research funds at least as large as their budget allocation. The government provides each center with the support of up to a billion yen and of up to several hundred million yen per year. Five percent of the research papers produced at WPI centers are papers drawing special attention and ranking in the top one percent of all papers.

As for cutting-edge research facilities, MEXT has designated particularly important research facilities as Specified Large-Scale High Technology Research Facilities. It is currently managing the Super Photon ring-8GeV (SPring-8), the SPring-8 Angstrom Compact Free Electron Laser (SACLA), the Super Computer "K," and the Japan Proton Accelerator Research Complex (J-PARC). All of these facilities are contributing to the findings of the most advanced research (refer to Chapter 2 for details). In addition, the "Academic Frontier Promotion Project," which started in FY 2012, supports large-scale academic projects in which a large number of researchers both inside and outside Japan participate, and international competition and collaboration are promoted. These projects are advanced strategically and are systematically based on the priorities as shown on the Road Map[1]. MEXT is providing support for the improvement and operation of these world-class research facilities.

As a measure to strengthen the research at universities, MEXT formulated the "University Reform Action Plan" in June 2012, a plan based on the challenges facing Japan and the conditions that are expected in the future. The plan indicates the direction of university reform in view of a new, ideal university. There are two pillars in this plan: the reconstruction of universities' functions during drastic changes in the socioeconomic structure and the improvement and enhancement of universities' governance. With these two major objectives, the plan shows eight basic directions for the reform, such as the enhancement of research capabilities. For national universities in particular, in 2013, each university is to establish the "National University Reform Plan," which illustrates the reform process by redefining each university's mission. Each university will receive strategic and prioritized support according to its mission and to promote the enhancement of its function. The universities are expected to create the most advanced research centers.

In 2013, the Program for Promoting the Enhancement of Research Universities is to be started. The program is designed to enhance the research capabilities of the whole nation by reinforcing universities that conduct world-class, excellent research activities. This program focuses on the academic research function universities have. There are several actions to be conducted in the intensive reform of research environments: securing and utilizing research management personnel who are in charge of research

1 SCJ established the "Master Plan" consisting of 46 large academic projects in all research areas. Based on this, the Research Environment Infrastructure Group of the Subdivision on Science published the "Road Map" (Basic concept of promotion of large academic projects—Road Map 2012—May 28, 2012), which listed evaluation results, challenges, and points to note regarding each project.

strategy and intellectual property management (based on the university's analysis of its research activities); accelerating competitive research; creating pioneering research areas; and developing international research environments. By supporting a ten-year reform plan which is an effective combination of these actions, the program aims to promote the enhancement of research capabilities and to reinforce universities that conduct world-class, excellent research activities. There are three viewpoints when determining which organizations will be supported: 1) the presence of many researchers, including young researchers, conducting quality research, 2) the existence of research activities that are producing international quality papers, and 3) the insurance that research results are disseminated to society. In addition to the indicators based on these three viewpoints, the strong points and weak points of each organization's research activities and its challenges are analyzed (the analysis of recruitment, internationalization, research disciplines and the research promotion system). Then, based on the organization's medium- and long-term policies on the enhancement of research capabilities and based on the scheme of the research environment reform to achieve their enhancement, the organizations that are to be supported will be selected.

A new examination on research conducted at independent administrative institutions has also started. Based on the legal adjustments related to R&D system reforms in other countries, such as the establishment of the America COMPETES Act in the U.S. and the revision of the Science and Technology Development Act in China, the "Act on the Enhancement of Research and Development Capacity and Efficient Promotion, etc. of Research and Development, etc. by the Advancement of Research and Development System Reform" was established in 2008. This law is intended to strengthen Japan's R&D capabilities and to improve the efficiency of R&D. The law designated 37 independent administrative institutions as "R&D Corporations" (as of November 2011). Article 6 of the supplementary provisions and the supplementary resolutions of both Houses state that what the most appropriate R&D Corporation is shall be examined.

A R&D Institution is an independent administrative institution that carries out R&D that is difficult for private companies and universities to perform, and is based on a national strategy. Such R&D includes R&D with a long-term perspective, highly public R&D, and R&D that currently carries high risk. Drastically enhancing the function of R&D Institutions is necessary for the creation of innovation. R&D Institutions are independent administrative institutions designed to improve the efficiency and quality of their operations. However, it was pointed out that the system should be modified into a new one that is based on the characteristics of R&D (long term, uncertainty, unpredictability, and specialization). For this purpose, the Comprehensive Strategy on Science, Technology and Innovation (cabinet decision on June 7, 2003) suggests that relevant ministries and agencies should work together to convert the R&D Institution system into a new, world-class system based on reviews of the entire system of independent administrative institutions. At that time, the achievement of efficient operation and accountability to the public should be major premises. The new system should meet the following requirements: 1) The primary goal shall be to maximize the results of R&D (achievement of missions). 2) Based on the national strategy, the definition of the R&D Institution (the research institution that deals with subjects that would be difficult for universities and private companies to tackle) shall be clearly placed within the whole system. 3) The law shall provide the need to secure highly-talented personnel with international competitiveness; the performance of technical evaluation that complies with an evaluation policy based on international standards; the establishment of a council for R&D under the supervision of the competent minister (foreigners may be appointed); the extension of the period for medium-term objectives; and the state of system operations as based on the characteristics of R&D. 4) The system shall be designed so as to achieve the review of pay levels, review of the objectives of streamlining business operations, improvement of procurement methods, review of the handling of personal income, and the flexible carry-over of budget.

(5) Activities for developing environments to achieve S&T-based innovation

We surveyed the situation for creating innovation based on the results of R&D in Japan. It revealed the following challenges:

- Companies have reduced the periods for research due to a decrease in research funds; thus, they refrain from conducting research with a long-term perspective or high-risk research.
- Cooperation between companies is still insufficient because of concerns about intellectual property and for other reasons. Industry-university-government cooperation also remains small in scale and is difficult to lead to industrialization.
- University-launched venture companies have difficulties with their business strategies after starting a business.

In order to tackle these challenges, it is necessary not only to secure research funds at companies, in order to respond to the management of venture businesses, and to promote joint research, but also to establish an industry-university-government cooperation system that will make it possible to develop the industrialization of research results. Here, we describe some new measures for this purpose: 1) COI STREAM, a new industry-university-government cooperation aimed at the creation of innovative results, 2) the deregulation and development of laws intended to promote research, 3) a project for promoting the industrialization of research results by investing in research institutions, and 4) research support by means of a tax system.

1) Construction of COI STREAM

In order for Japan to survive international competition and revive its economy, it is important to continuously create radical innovations.

COI STREAM, a program to be launched by MEXT in 2013, is intended to achieve radical innovation that could not be achieved by a company alone by removing the walls between research fields and organizations and by forming industry-university collaboration. This goal is pursued by developing "visions" (what society and life should be like in the future), which are derived from the needs of a future society and, based on the visions, by specifying novel R&D subjects that would become meaningful in 10 years.

To be specific, COI STREAM intensively supports R&D conducted by large-scale, cooperative research teams (centers). Based on the visions to be achieved, the teams set specific objectives (by the back-casting method) to address challenges that are difficult to solve, yet would have positive social and economic impacts if they were solved. They work on R&D subjects that are already in the stage of basic research and aim for their practical application. In COI STREAM, the three parties work as a team; the government takes risks and universities and companies combine their resources to solve these challenges.

Universities and companies tackle challenging and high-risk R&D together, in a shared center where their roles divided, and they apply the results to society as quickly as possible. In this way, the program aims to develop a system that will continuously create radical innovations.

As for the practical application and industrialization of the results, in order to seamlessly connect the results (spin-offs of COI) to business, the program provides opportunities for business negotiations with a view to tie-ups between companies while also including collaboration with financial institutions. COI also has a plan to strengthen an exit strategy in coordination with the related policies of relevant ministries and agencies. In addition, as for the management of the centers, both a research team and a management team consisting of specialists are formed. According to an optimal business model and an intellectual property strategy, the team attempts to build a system for continuously creating new values and markets by closely matching social needs with technological seeds. These are the features of the project.

The project greatly differs from former projects in that the project is not a "seeds-pushing-type" industry-university-government collaboration that searches for applications for its research results; instead, it sets and promotes R&D subjects that are deduced from the visions that have been developed based on the needs of a future society.

Column 1-5 Attempts of the Kobe Biomedical Innovation Cluster —aiming at the practical application and industrialization of research results

Under the scheme of concentrating medical-related industries by developing a next-generation medical care system having an advanced clinical research capability and a medical care capability, Kobe City has been constructing the "Kobe Biomedical Innovation Cluster" in Port Island (a man-made island) since 1998. The initiative to construct Japan's first life-science cluster that aims at becoming Asia's number one is drawing attention.

There are a wide range of medical-related facilities in the Kobe Biomedical Innovation Cluster, from life-science research institutions that address basic research to medical-related companies and hospitals that provide treatment using technologies that have been put into practice. As of March 2013, there were 233 related institutions and companies, and their employees numbered about 5,200 people. The Kobe Municipality estimated the economic effects produced by the activities of the Kobe Biomedical Innovation Cluster to be at 10.41 billion yen (FY 2010).

In the process of constructing the Kobe Biomedical Innovation Cluster, the Kobe Municipality first made a great effort to establish the RIKEN Center for Developmental Biology, which is the core of basic research, and the Institute of Biomedical Research and Innovation, which serves as a bridge linking the research stage to the practical application stage. In this way, a basic system that produces the effects of accumulation has been constructed. Since then, the formation of the cluster has accelerated. The Kobe City Medical Center General Hospital, which plays a central role in standard medical care, has moved in, and "K computer" has started its operation. Advanced medical care facilities, such as the Kobe Minimally Invasive Cancer Center and the KIFMEC[1], have also been established. The whole cluster was designed so as to relate these research centers to each other, and other related companies were invited. A seminar intended to introduce a company that has newly moved into the cluster with other companies, and a seminar to promote exchanges is held each month in order to enhance the effects of accumulation. In addition, tax incentives and deregulation for the companies that have moved in are promoted by the whole cluster using the comprehensive special zone system.

According to a questionnaire given to companies in the cluster, what they emphasize and are very satisfied with are the following: the ease of developing personal contacts and personal networks, the ease of getting the latest information, the ease of collaboration with research institutions and universities, and the convenience of having access to the airport, etc. In addition, some companies note: information about the scenes at hospitals is available; and there is plenty of intellectual stimulation which is effective in maintaining the motivation of researchers. As for concrete research cooperation, as a result of the joint-research opportunity, some companies have moved into the cluster. The seminars for exchanges have also triggered new cooperation. This kind of cooperation is expected to develop further in the future. Regarding research activities, the research on retinal regeneration using induced pluripotent stem cells (iPS cells) has been making progress in a joint research project among RIKEN and the Institute of Biomedical Research and Innovation, and the world's first clinical research on iPS cells is about to be carried out.

Research cooperation taking advantage of the cluster are also being advanced, including research on regenerative medicine using stem cells, like iPS cells; research on the development of drug-discovery; and research on drug-discovery innovation using the "K computer." Efforts for the practical application and industrialization of these research results are energetically being made. Thus, the effect of developing new products is expected to show up in the future.

2) Measures by means of deregulation

Regulations and systems sometimes get in the way of using research results. The Council for Regulatory Reform pointed out, "Examinations on medical equipment in Japan imposes detailed requirements regarding material and size, which serves as an obstacle to the innovation created by manufacturers. There was even a case in which, because a product barely failed to comply with Japanese Industrial Standards that were specified as the certification criteria, a company gave up applying for certification and, instead, deferred to a registered certification authority. Detailed information on raw

1　Kobe International Frontier Medical Center materials that is not required in the examinations conducted in Western countries is required in Japan. Furthermore, a change review is required every time specifications are modified. Such inefficiency exists only in the Japanese certification system." The council then pointed out the need to review the certification criteria in view of accelerating examinations on the characteristics of medical equipment.

In order to provide patients with swifter treatment, the Council for Regulatory Reform is working on a policy to give regenerative medical products conditional approval within a specified time limit as long as their effectiveness and safety are ensured. It also stated the opinion that, "In case health damage occurred, a compensation system should be prepared for the relief of victims."

"The Act on the Comprehensive Promotion of Measures to Allow the General Public to Promptly and Safely Receive Treatment with Regenerative Medicine," was promulgated in May 2013, and it states, "Measures should be promoted to provide the general public with opportunities to use regenerative medicine before the rest of the world," and "In order to promote R&D, the provisions for and dissemination of regenerative medicine, be they statutory, financial, or taxation measures, shall be taken if considered necessary."

The RIKEN Center for Developmental Biology and the Institute of Biomedical Research and Innovation have jointly conducted "clinical research on the transplantation of retinal pigment epithelium sheets derived from home-made iPS cells to exudative, age-related macular degeneration." In February 2013, they applied to the Ministry of Health, Labour and Welfare for examination of their research. This is Japan's first application for the examination of clinical research using cells derived from iPS cells. It is hoped that deregulation will promote such efforts.

3) Industrialization of research results produced at universities and R&D funds provided by the government and the private sector

As for the challenges in using the results of industry-academia cooperation, companies mentioned the shortage of "funds for development" and "funds for industrialization" (refer to Figure 1-2-27). JST's "Collaborative Project for Practical Application Development" supports development funds for industrialization that are led by companies using technologies developed at universities in order to accelerate company-led industrialization of excellent research results produced at universities. One of the features of the measure is that if the practical application or industrialization of research results has succeed within five to ten years of the development period, the supported company must repay its research funds to the government in-full, but if the development is unsuccessful, the company must only pay 10% of that amount. This feature allows companies to actively try high-risk R&D using external technologies owned by universities. Such R&D was difficult for companies to perform on their own. In addition, the government finances four national universities in order to support the industrialization of their research. If they have projects whose quality research results are close to the industrialization stage, the universities will then steer the projects to businesses within five to ten years, allowing for joint research with companies.

Additionally, the government has established a foundation for the enhancement of innovation bases and the creation of new businesses managed by the Development Bank of Japan. The foundation is designed to create new businesses in cross-industrial collaboration and to create new businesses that use advanced technologies that are lying idle in universities. The government also offers support to the Innovation

Network Corporation of Japan for its assistance to venture businesses and for the industrialization of advanced technologies.

Column 1-6

The Need for Experts on both Technology and Management

It is a long time since the serious question, "Why do Japanese companies having sophisticated technology lose in business?" was first asked. Whether researchers or entrepreneurs, those who establish an agenda in view of the needs of a future society must not only have knowledge about S&T but must also have a thorough knowledge of both technology and management. In addition, as shown in Figure 1-2-29, university-launched startup companies have difficulties with management after starting their business. In order to respond to rapid changes in the needs of the market, the Council for Industrial Competitiveness has discussed the development of personnel who can create business models with a wide view of technology and management. Those who will be developed as personnel having such abilities are called "Management and Technology" (MOT) talents.

It is often pointed out that Western companies have good management skills. The existence of many excellent business schools is mentioned as a system that fosters management talents who lead such excellent management. We should pay attention to the fact that business schools in Asian countries, such as India and China, have recently made remarkable progress due to collaboration with business schools in Western countries. The Council on Competitiveness-Nippon (COCN) produced a report, entitled "Human Resource Development for the Creation of Innovation," to provide topics and suggestions for enhancing the innovative power of personnel at companies. The report pointed out the need for a system that increases opportunities by directly utilizing management, cultures, and ways of thinking in different industries and nations. It suggested expanding the types of courses for training executives at business schools in Japan. University-launched startup companies also have difficulties with management after starting their business. It is thus necessary to swiftly establish an educational system that can develop personnel who have knowledge of both technology and management skills.

4) Research support by means of tax systems

By using a tax-credit system for special experimental and research costs, companies can receive tax credits at a higher rate than usual for a specific proportion of R&D expenditure spent in joint research with universities and conducted as part of a contract involving sponsored research or joint research with universities or public research institutions. Private companies' R&D investment accounts for about 70% of the total amount of R&D investment in Japan. Promoting this investment is essential to the enhancement of Japan's growth and to its international competitiveness through the acceleration of innovation. It is therefore necessary to use tax systems to promote R&D investment.

3 Building International Research Networks

Building international research networks has become increasingly important in order to produce and develop creative research results and to lead them toward the creation of new values. It is important to organize strategic measures for building and using international research networks and for achieving innovation within Japan as a result of these networks.

(1) Problems in building an international research network through vitalization of international brain circulation

1) International brain circulation of researchers

Science and technology is not limited much by geographic constraints. The development of information and communication technology such as the Internet has accelerated the circulation of knowledge across national borders. Accordingly, S&T activities have been linked to each other more closely than ever before.

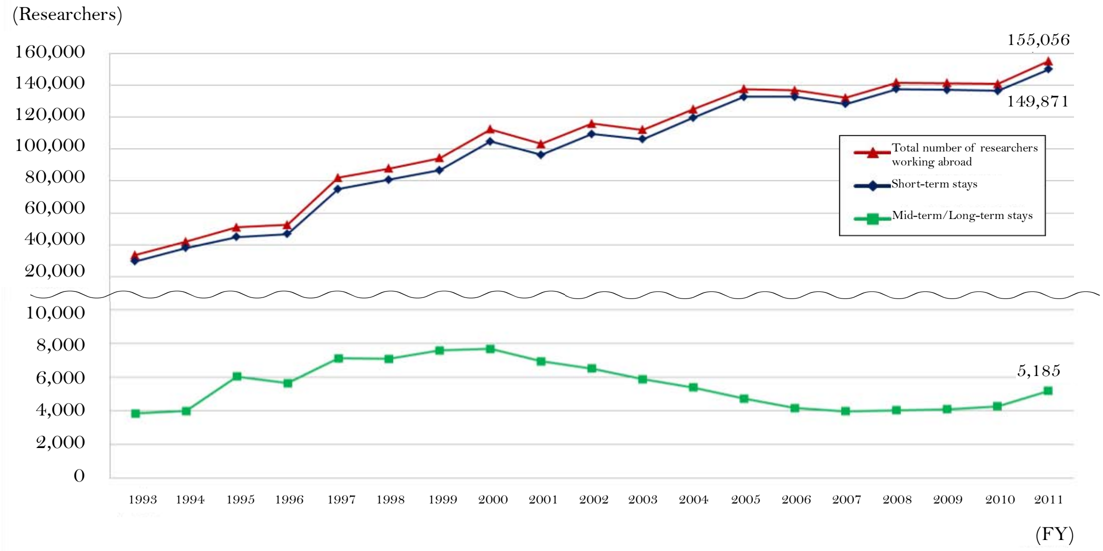
In order to use circulating knowledge and the results of international S&T activities for the further creation of new knowledge, developing and securing excellent personnel is important. Many of the world's leading researchers have developed by moving from country to country, and from organization to organization, while always aiming for new frontiers in S&T. In the same manner, it is also very important for Japan to establish and use international research networks for the development of researchers and young researchers, to use a variety of highly-talented personnel, including foreigners, and to activate the international movement of personnel.

CST's International Committee reported the effects of sending researchers abroad in its "Strategic Development of International S&T Activities Based on the 4th Science and Technology Basic Plan" (January 2013). The report summarizes the expected effects of Japanese researchers as follows: 1) they will develop their research capabilities by participating in advanced research conducted in other countries, 2) they will directly experience world-class research and research communities, and 3) they will participate in international research networks and acquire the ability to play a key role in these networks. It also summarizes the expected effects of inviting foreign researchers as follows: 1) they will promote research in Japan by learning the knowledge and skills foreign researchers have, 2) they will develop research environments in Japan where researchers vie with each other at the international level, and 3) they will contribute to establishing international human resource networks and research networks with Japan as their core.

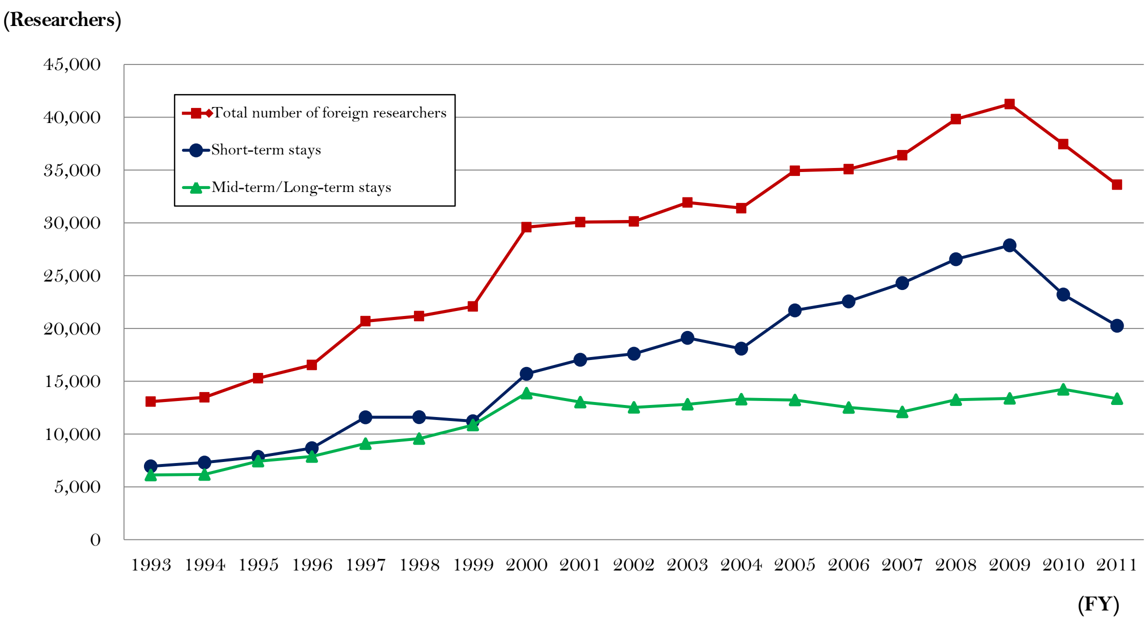
Next, we examine the present state of foreign researchers working in Japan and of Japanese researchers working abroad. The number of researchers working abroad, including short-term stays and mid-term/long-term stays, used to be on the rise, but it has remained at the same level since FY 2005. Although, it increased by about 10% in FY 2011. When we pay attention to the number of mid-term/long-term stays only, it had been decreasing for several years since FY 2000. It then showed signs of increase again, but the number for FY 2011 still falls below 70% of that of FY 2000 when it was at its peak. As for foreign researchers, the number of short-term stays (a period of 30 days or less) had been increasing, but it significantly decreased in FY 2010 and FY 2011. The decrease is presumed to have been affected by the GEJE, which occurred in March 2011. On the other hand, the number of mid-term/long-term stays of foreign researchers has remained at the same level for the past 10 years. As a whole, the numbers for mid-term/long-term stays for both researchers working abroad and for foreign researchers have remained at low levels (Figure 1-2-31).

Figure 1-2-31 / Transitions in the Number of Researchers Working Abroad and in the Number of Foreign Researchers

Transitions in the Number of Researchers Working Abroad by Their Duration of Stay (Short-term, Mid-term/Long-term)



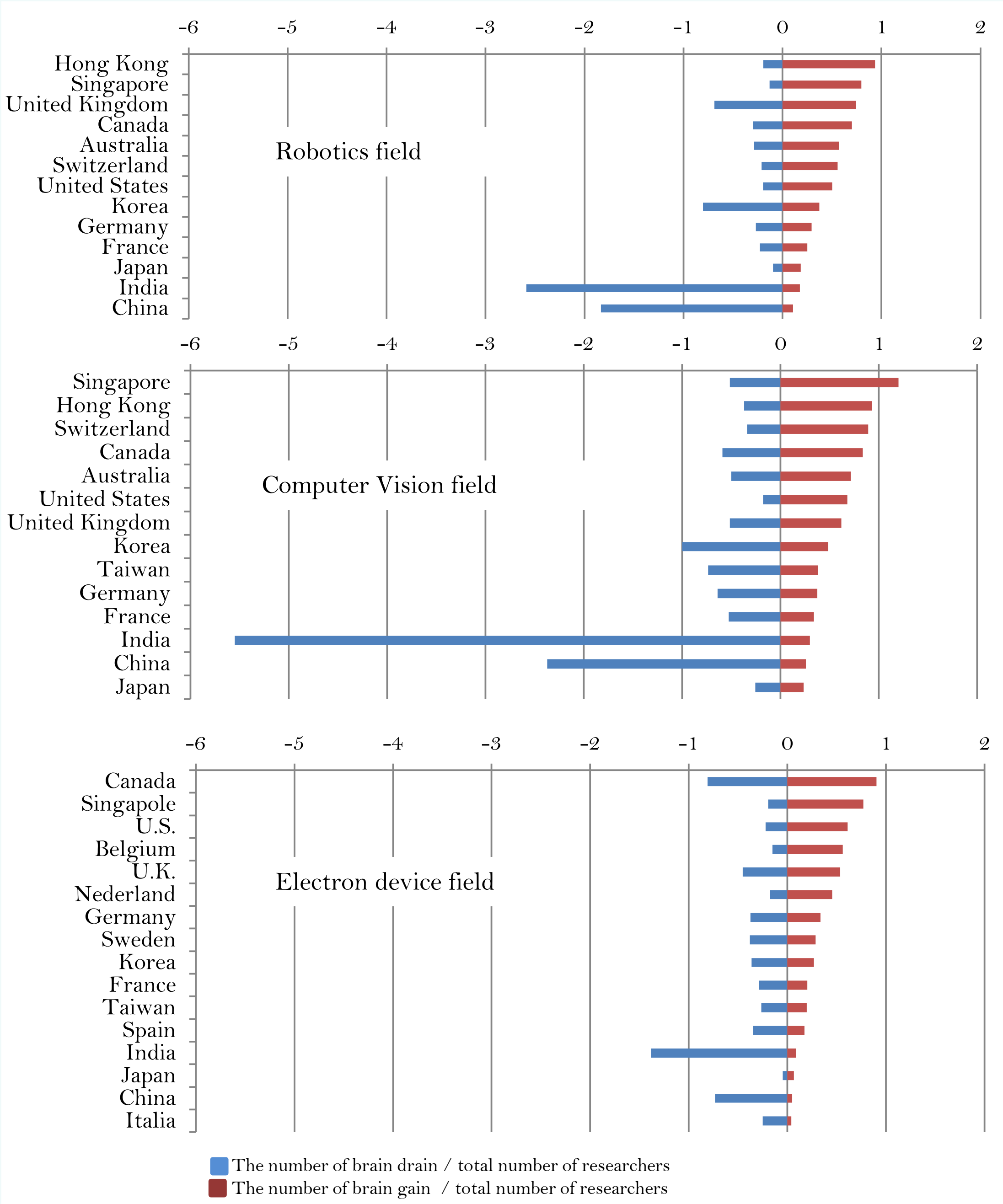
Transition in the Number of Foreign Researchers by Their Duration of Stay (Short-term, Mid-term/ Long-term)



Notes: 1. In this survey, "Mid-term/long-term" refers to a period of more than 30 days and "short-term" refers to a period of 30 days or less.
2. Post-doctorates, etc. have been included in the numbers since FY 2008.
Source: MEXT, "Survey on International Research Exchanges" (June 2013)

It is often pointed out that the international mobility of Japanese researchers is lower than that of those from other developed countries. Regarding this point, the National Institute of Science and Technology Policy examined data on approximately 7,000 researchers who published papers in major academic journals in the fields of robotics, computer vision, and electronic devices. It then extracted the authors' affiliated organizations awarding their degrees (bachelor's degree, master's degree and Ph.D.) and the countries as well as their affiliated organizations when they published their papers. (Figure 1-2-32).

Figure 1-2-32 / Comparison of the Number of Researchers Who Moved Internationally by Country or Region (the Ratio of the Number of Researchers Who Moved Internationally to the Number of Those Surveyed in Each Country or Region)



Notes: 1. These countries are main countries which have above 20 researchers.
2. Horizontal scale is normalized by the number of researchers of each country.
3. These data are quantitatively analyzed by comparing the authors' affiliated organizations and the organizations awarding bachelor's degree which are extracted from author biographies.

Source: NISTEP "Quantitative Analysis on International Mobility of Researchers Based on Author Information" (August 2011)

Let us take a look at the computer vision field. In view of "brain gain" (indicated by the red lines in the figure), in Singapore, the ratio of the number of researchers who earned a bachelor's degree abroad is high when compared to the total number of researchers who published papers. In view of "brain drain" (indicated by blue lines in the figure), in India, the rate of the number of researchers who earned a bachelor's degree at the country and then moved to overseas research institutions is high when compared to the total number of researchers who published papers. This comparative survey shows that the international mobility of Japanese researchers in those fields is lower than that of those in Western countries and in other Asian countries.

Even in the fields of robotics and electronic devices[1], where Japan is estimated to have a relatively strong presence, the international mobility of researchers immigrating and emigrating to and from Japan is low. Thus, the situations in other fields are of especially serious concern.

The situation of international brain circulation is being investigated in many ways.

As for the researchers working abroad, the CST International Committee's report points out that the underlying reason that mid-term/long-term stays are decreasing is that researchers are concerned about securing a post after coming back to Japan. Based on the results, the committee states that it is desirable to adopt a viewpoint of positively evaluating the mid-term/long-term stays at overseas research institutions not only in terms of international exchange programs but also in terms of general research support programs.

On the other hand, regarding foreign researchers working in Japan, the 2012 NISTEP Expert Survey on Japanese S&T and Innovation System[2] strongly recognizes that the number of foreign researchers is insufficient. Researchers' opinions about the challenges of inviting foreign researchers to Japan are as follows: 1) the level of research should be high enough to attract them, 2) more cooperation with overseas universities and research institutions is needed, 3) in order to attract excellent foreign researchers, the salaries and research facilities need to be world class, 4) arranging appropriate living environments for their families and for the education of their children is needed, and 5) a system for completing the paperwork in English should be developed.

In conclusion, in order to establish international research networks, it is necessary to develop research environments that allow researchers to actively carry out research in other countries. In order to attract excellent foreign researchers, it is also necessary to make the domestic research environments more attractive with due consideration for the living environments provided to researchers and their families.

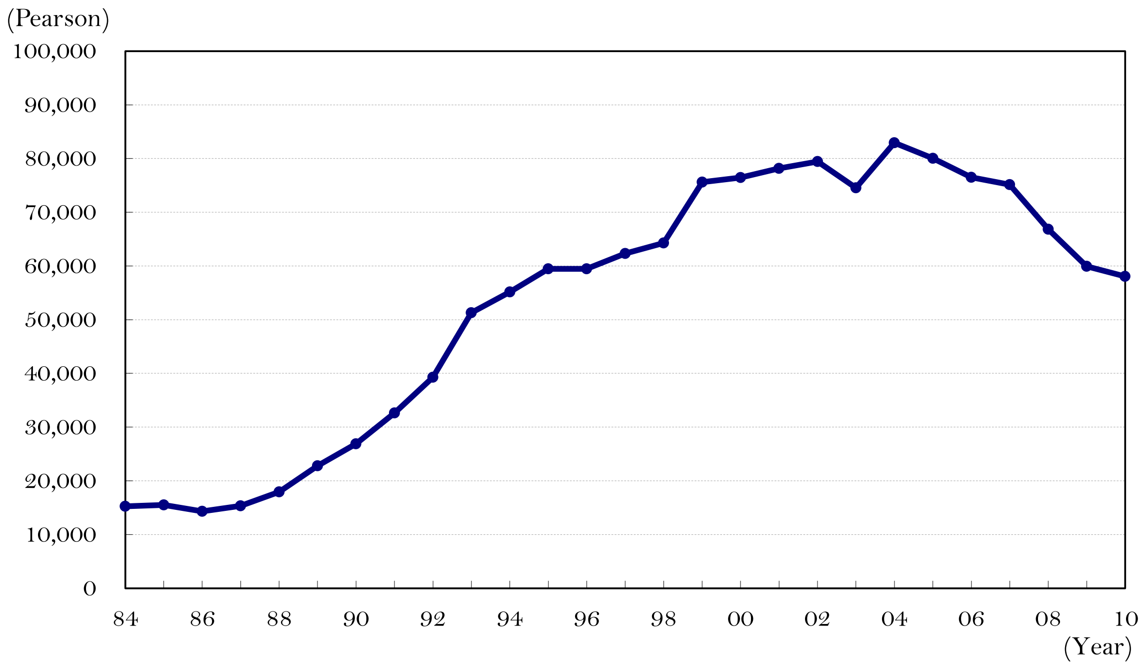
2) The situation of student exchanges between Japan and other countries

Studying abroad provides an important opportunity for students to acquire good language skills and communication abilities, to experience different cultures and to develop as capable people who play active roles in the international community. Although we cannot jump to a conclusion based only on the number of students who study abroad, the results of the compilation based on the OECD's statistics show that the number of Japanese students studying abroad has been on the decline since FY 2004 (Figure 1-2-33).

1 According to the survey, countries with a strong presence in terms of publishing papers are as follows: the U.S., Japan, Spain, and Germany in robotics; the U.S., the U.K., and France in computer vision; and the U.S., Taiwan, Japan, Korea and China in electronic devices.

2 NISTEP, "Analytical Report for 2012 NISTEP Expert Survey on Japanese S&T and Innovation System" (April 2013)

Figure 1-2-33 / Trend Line for the Number of Japanese Students Studying Abroad



Source: Created by MEXT based on UNESCO Statistical Yearbook, OECD study, IIE, study by China's Ministry of Education, etc.

Next, we examine the number of Japanese students abroad and the number of foreign students being hosted in Japan by comparing the numbers of Japan with those of other countries (Figure 1-2-34).

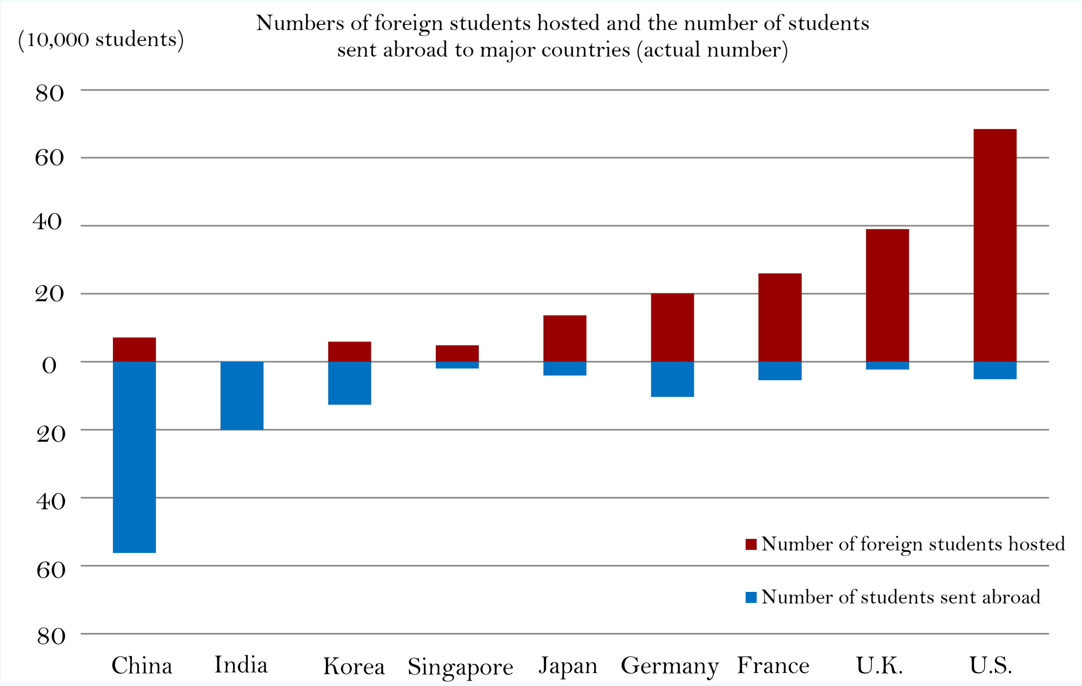
We should be careful when comparing these numbers because the population varies from country to country, yet both the number of Japanese students going abroad and the number of foreign students hosted in Japan are smaller than those of the U.S., the U.K., Germany, and France. For hosted students in particular, even when comparing the percentage of students hosted versus the population of each country, the percentage of students hosted by Japan is smaller than that of the other countries. On the other hand, the number of Japanese students studying abroad is the second smallest among the U.S., the U.K., Germany, France and Japan, with the U.K. having the smallest number. When comparing the percentage of students studying abroad versus the population of each country, the percentage of Japanese students is again the second smallest, with the U.S. having the smallest percentage of students studying abroad.

According to a questionnaire given to national universities[1], the main hindrances to Japanese students' studying abroad include negative effects on the limited period for job hunting in Japan, the financial burdens of going overseas, the insufficient support systems of universities and the poor foreign language skills of Japanese students. As mentioned above, the number of students studying abroad and the number of students hosted by Japan are smaller than that of the U.S., the U.K., and other countries. We are

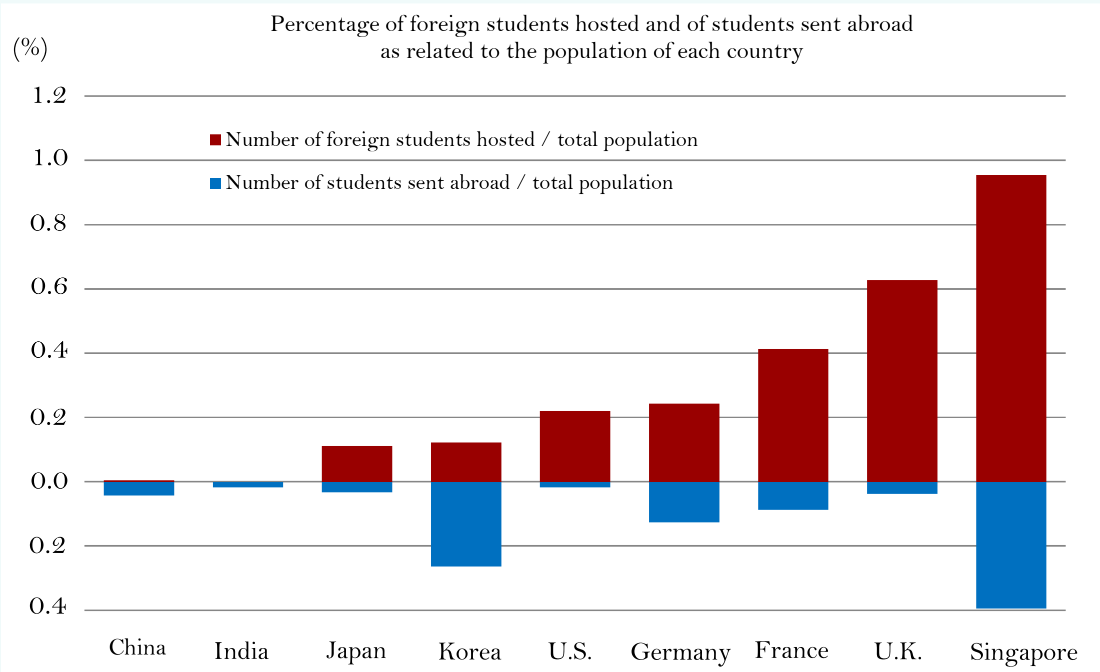
1 The working group for the improvement of exchange programs (in the Committee for International Exchange of the Japan Association of National Universities) sent the questionnaire to each national university in January 2007 and 87 universities answered.

concerned that these impacts will mean that Japanese students will have fewer opportunities to develop a deeper awareness of the world and that they will be unable to encounter different cultures and different ideas while they are students. Furthermore, this may cause a negative attitude in regard to their participation in international research networks once they become researchers. It is thus important to further promote the exchange of students, both by sending more Japanese students abroad and by Japan's hosting more foreign students.

Figure 1-2-34 / Number of Foreign Students Hosted and the Number of Students Sent Abroad to Each Country (Actual Number and Percentage in the Population)



Source: Created by MEXT based on the data from the UNESCO Institute for Statistics "Global flow of Tertiary-level Students" (March 2013)



Source: Created by MEXT based on the data from the UNESCO Institute for Statistics "Global flow of Tertiary-level Students" (March 2013)

3) International research networks appearing in internationally co-authored papers

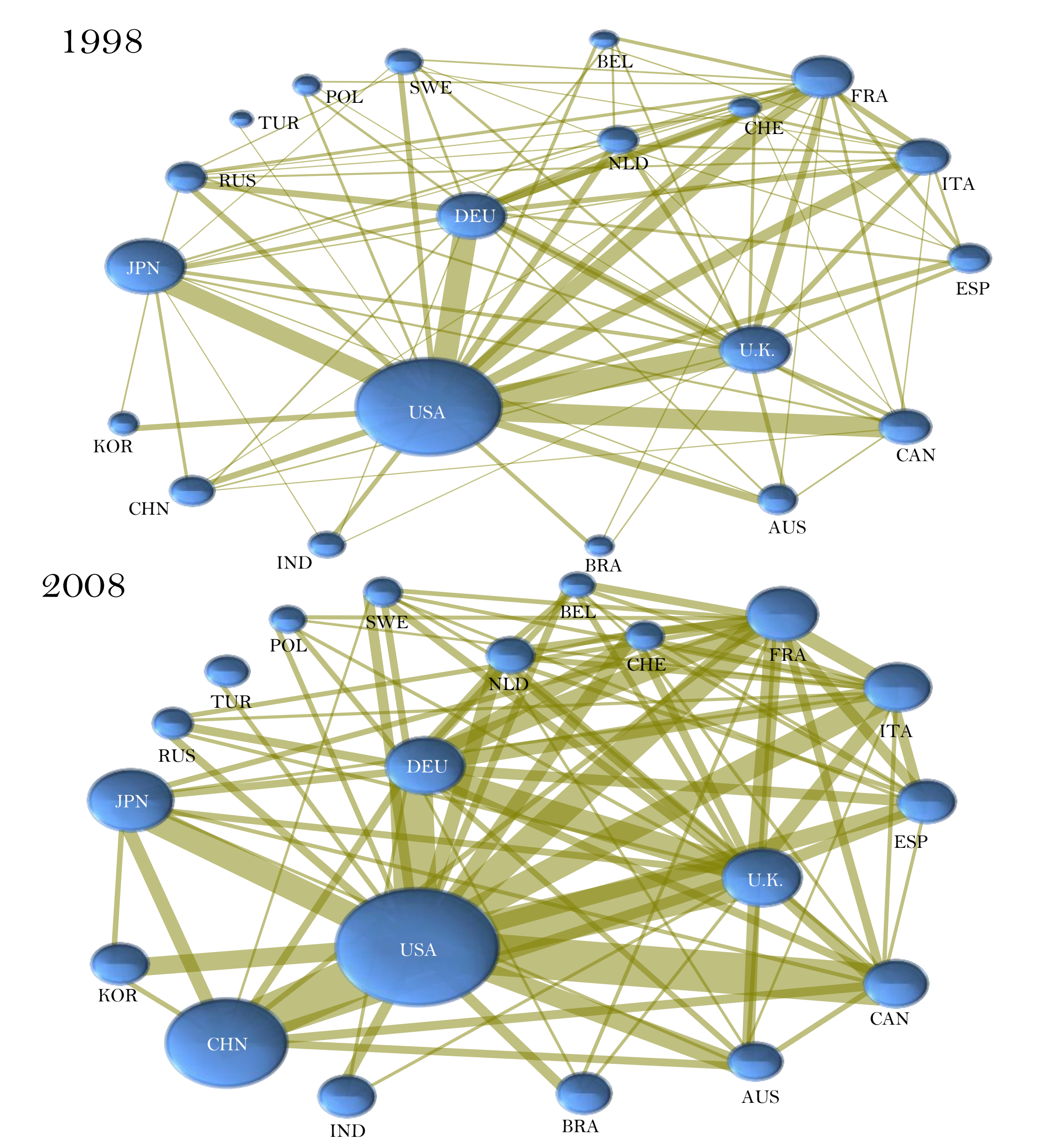
In Part 1, Chapter 2, Section 1, 1, (1), 1), we demonstrated how internationally co-authored papers were more frequently cited than those written by a single author or than those that were co-authored by authors belonging to the same organization within a country (domestic papers); thus, cooperation among researchers who are working in different countries or regions could produce better results.

Figure 1-2-35 shows research papers and internationally co-authored papers produced in the world in 1998 and 2008 for comparison. The number of internationally co-authored papers is shown by the thickness of the line connecting two countries. The number of internationally co-authored papers significantly increased between 1998 and 2008 as the globalization of S&T activities advanced. At the same time, co-authorships among Western countries, such as the U.S., Germany, the U.K., France, Italy, and Spain, increased; thus, we can see the relationships forming a group. On the other hand, Japan has greatly strengthened its relationship with China, but its other lines (the number of co-authored papers) are mostly thin when compared to those of Western countries. This seems to show that Japan has left behind the development of international networks of knowledge. In addition, as described in the previous subsection, the number of internationally co-authored papers produced in Japan has not increased much when compared with that of other major countries (Figure 1-2-1). These situations indicate that Japan's S&T activities are failing to keep up with the pace of globalization.

Based on these situations, in the report, "What the Science and Technology Policies Should be in the Future in View of the Great East Japan Earthquake (suggestion)" (January 2013), CST points out that in order to promote new research and to improve the efficiency of research, when establishing a research system, it is necessary to invite the best qualified researchers from a wide range of areas both inside and outside Japan. It then points out that it is essential to build extensive international networks of young researchers.

Western countries are currently developing international research networks and promoting international brain circulation. When excellent researchers connect with each other across national borders to jointly conduct research, their research activities are vitalized and this situation is considered to be a basis for achieving innovation. In order to vitalize S&T, which is the basis of innovation, Japan also needs to step up its efforts to activate international brain circulation and to establish international research networks.

Figure 1-2-35 / Changes in the Trends of Research Papers and Internationally Co-authored Papers (1998 and 2008)



Notes: 1. Center of each country is relatively same position between figure of 1998 and one of 2008. The area of each circle indicates the number of publications in science category.
2. A line between circles indicates the internationally co-authored papers and its width is proportional to the number of papers.
3. Integral count method is used. The publications from China are increased and internationally co-authored papers among U.S and EU are strongly increased.

Source: Created by NISTEP based on "OECD Science, Technology and Industry Outlook 2010."

(2) Measures to activate brain circulation and to establish international research networks in other countries

Competition for excellent researchers has intensified as knowledge circulates throughout the world. The number of foreign students who are expected to play key roles in research in the future also has increased. Here we examine some of the measures taken in other countries to activate international brain circulation.

1) Measures taken in the U.S.

The U.S. draws highly-talented personnel from all over the world and their performance in the S&T fields is remarkable. For example, when we analyze where the first authors of research papers are from, about 30 percent of the first authors who are young researchers are from Asia, including Japan, and about 20 percent are from Europe. About 20 percent of the first authors who are senior researchers are from Asia while about 10 percent are from Europe (Table 1-2-36). The country that hosts the largest number of foreign students is the U.S. (Table 1-2-37). Furthermore, more than 70 percent of foreign Ph.D. students majoring in science and engineering want to continue staying in the U.S. after graduation[1]; thus, we can say that the U.S. maintains its vitality by drawing excellent researchers and foreign students from the world.

Table 1-2-36 / Countries of Birth for the First Authors Working in the U.S.
(Survey by Random Sampling, Universities, Natural Sciences)

Birth country of the first authors / Categories of researchers	Japan	China	Other Asian countries	Europe	U.S.	Others, Unknown
Young researchers (n=299)	2.7%	14.7%	13.7%	20.4%	37.8%	10.7%
Senior researchers (n=307)	3.3%	6.5%	13.4%	13.7%	53.7%	9.4%

Notes: 1. The survey was conducted by randomly sampling papers from the database and sending a questionnaire to the authors of the papers.
2. The results covered papers whose authors were listed by the degree of authors' contribution to the focal paper.
3. Young researchers include students and post-docs. Senior researchers include lecturers, assistant professors, associate professors, and professors.

Source: NISTEP, "Knowledge creation process in science: Basic findings from a large-scale survey of researchers in Japan and the U.S." (December 2011)

1 From a survey conducted by The National Science Board between 2004 and 2007

Table 1-2-37 / Major Countries Hosting Foreign Students (2010)

Countries	Percentage	Countries	Percentage
U.S.	16.6%	France	6.3%
U.K.	13.0%	Canada	4.7%
Australia	6.6%	Russia	3.9%
Germany	6.4%	Japan	3.4%

Source: Created by MEXT based on OECD, "Education at a Glance 2012"

Two possible reasons that the U.S. draws fine researchers from around the world are that 1) the U.S. produces a far larger number of quality papers, such as those ranking in the top 10 percent or even in the top one percent of all papers, as compared with other countries, such as those described Chapter 1 (Figure 1-1-14), and 2) most of the universities listed in the world's top 10 universities are located in the U.S. (Table 1-1-37). Many researchers emigrate from the rest of the world to gather in the U.S. where excellent research activities are performed, and they contribute to furthering the promotion of research activities in the U.S.

The U.S. has continued taking advantage of overseas personnel. With enhanced fellowships and preferential treatment in issuing visas, in addition to the quality of the research activities that are drawing overseas researchers, the U.S. government has also developed pleasant working environments for highly-talented overseas personnel. Simultaneously, the U.S. is actively fostering domestic S&T talents from within. For example, the Obama Administration is strongly promoting the development of domestic S&T talents by emphasizing STEM education (Science, Technology, Engineering, and Mathematics).

The U.S. has also actively accepted highly-skilled personnel, both immigrants and non-immigrants, to attract professional workers and to enhance its international competitiveness. In addition, the government is considering preferential treatment to foreign students who have majored in the STEM fields and who have earned either a master's degree or a doctor's degree at a U.S. university.

2) Measures taken in Europe

In 2000, the EU formulated the Lisbon Strategy with the aim of "making the EU the most competitive and dynamic knowledge-based economy in the world by 2010." The strategy specified the promotion of R&D as a major objective and suggested increasing the mobility of researchers within the EU, as well as coordinating research programs, increasing the amount of research funds, and establishing the European Research Area (ERA) to create the common market of R&D within the EU.

In order to achieve ERA, the EU developed the Framework Programmes for Research and Technological Development (FP) covering multi-year periods. The Seventh Framework Programme (FP7, 2007 to 2013) is currently promoting R&D. FP7 consists of the Joint Research Center, which is directly operated by the EU, and includes R&D programs based on the four following categories: 1) Cooperation (funding programs for joint research in 10 key areas), 2) Ideas (the European Research Council funds research in interdisciplinary areas and in new areas and research with high risk, high return, and high impact), 3) People (Marie Curie Actions promotes human resource development and international brain circulation), and 4) Capacities (provision of research infrastructure and other tools for research). Marie Curie Actions, in particular, seems to be playing an important role in the promotion of brain circulation by providing support for researchers from an EU member state to conduct research in another EU member state; by inviting world-class researchers outside Europe; by providing support for researchers from EU member states to conduct research at research institutions outside the EU on condition that they will return to the research institutions in their states; and, by providing support for researchers from EU member states who have conducted research outside the EU for five years or more to return to research institutions in the EU. In addition, FP7 provides funds for joint research that is conducted by institutions located in three or more states so as to promote multilateral research cooperation.

The medium-term evaluation report on FP7, produced by an expert panel and published by the European Commission in 2010, cited the following valid points: "Participation of a wide variety of researchers is making high-quality research possible," and "Marie Curie Actions have enhanced the international mobility of researchers and human resource development."

3) Measures taken in China

Since the 1990s China has specifically promoted the following measures: intensive R&D investment in a few, select institutions, the dispatching of its workers to developed countries, and the policy to lure back talented personnel through generous treatment. Aiming to invite talented personnel having "high goals, high standards and high intensity," the Chinese government provides selected excellent researchers with research funds, salaries, medical insurance, and various allowances ("The Program for Inviting Overseas Outstanding Talents," "The Program for Fostering 100 Excellent Chinese Researchers" and "The Program for Inviting Overseas Renowned Scholars"). In addition, China is advancing the "Sea Turtle" policy, in which able Chinese researchers residing overseas are lured back to China. It is presumed that they are forming networks that include overseas research institutions.

In 2011, China succeeded in inviting the U.S. Cold Spring Harbor Laboratory, one of the world's top laboratories in the life sciences field, to Suzhou, and together they launched Cold Spring Harbor Asia. The world's top researchers have also been invited to this laboratory, which has greatly contributed to establishing international research networks in China.

4) Measures taken in Korea

Korea is a nation oriented around the concept of a global-community. Therefore, companies and universities in Korea give important positions to people who have experienced studying abroad, and many of its students go abroad to study. The number of Korean Ph.D. students who study abroad is 7.5 times greater than that of Japan. This global-community-oriented way of thinking has improved their English language skills; and the average TOEFL score of Koreans was 1.2 times higher than that of Japanese students (in 2009). Many renowned professors at Korean universities typically gain a doctor's degree at a university in another country. Large companies in Korea also emphasize English language skills when hiring new employees. In this way, the entire society of Korea places tremendous value on personnel who are able to respond to globalization.

Universities in Korea are also actively inviting highly-talented personnel from other countries. The developing project of the World Class University (WCU), which the Lee Myung-bak Administration has promoted since 2008, provides large-scale support for universities to invite world-class researchers and leading engineers as part-time professors for joint research. The Korean government is currently developing an international science and business belt with the Institute for Basic Science as its core facility. The Park Geun-Hye Administration announced a plan to invite 300 scientists who rank among the world's top one percent to this facility. As a measure to promote the hosting of highly-skilled foreign personnel, there is also a system to permit those having a card especially issued for highly-skilled personnel to enter and leave the country a limitless number of times during the period of their residency (1658 scientists had been issued the science card as of May 2013). In addition, with support from both the national and local governments (Kyonggi Province) the French Institute Pasteur was also invited inside the country (Institute Pasteur Korea, established in 2004, had about 150 employees as of 2011). As shown in this example, the Korean government is positive about inviting overseas research institutions.

In this way, based on support from its global-community-oriented society, the Korean government is actively promoting measures to enhance international brain circulation.

(3) Measures taken in Japan to establish an international research network by activating international brain circulation

Measures for international brain circulation in Japan include the promotion of international exchanges of researchers and participation in international research networks. It is important to organically unite these measures.

1) Promoting the international exchange of researchers

The Japanese government has been promoting the "Strategic Young Researcher Overseas Visits Program for Accelerating Brain Circulation[1] (JSPS)" since FY 2010. This program provides support for the universities and research institutions that offer young researchers opportunities to work abroad and to participate in international joint research with a research institution there in order to foster excellent researchers who will play a key role in international research networks in Japan through the international exchange of researchers. One of the features of the program is that young researchers work at an overseas organization while they remain part of an organization in Japan so as to act as a bridge between a university or a research institution in Japan and the counterpart in another country for the purpose of conducting international joint research.

The "Postdoctoral Fellowship for Research Abroad" program (JSPS) provides support for individual researchers who try to conduct research at an overseas university or a research institution. They are like "knights errant" who look for adventures in different cultures. The experiences they have gained are more precious than anything else. Young researchers are expected to actively participate in the program. It is also important to foster deep awareness of the world before working abroad by taking advantage of any opportunities for student exchanges or other programs.

We have indicated in (1), 1) of this subsection that when researchers go abroad to work, they are

1 This is the name of the program in FY 2011 and FY 2012. It was "Young Researcher Overseas Visits Program for Activating Brain Circulation" when the program started in FY 2010.

concerned about their posts after coming back to Japan. The Strategic Young Researcher Overseas Visits Program for Accelerating Brain Circulation sends young researchers abroad while securing posts for them after they come back to Japan. Universities and research institutions need to establish networks according to each organization's international research strategy by making the most of this program. In addition, the Tenure Track System, which is intended to secure posts for young researchers to independently conduct their activities, offers job opportunities to excellent young researchers who have an experience of conducting research abroad. Universities and research institutions need to understand the usefulness of this system and to make efforts to establish and improve the system, for example, by making the system known to all in the organization. It is also important for society and academic circles to highly evaluate personnel who have actively worked abroad as a driving force for international mobility, as is the case in China and Korea.

On the other hand, the "Postdoctoral Fellowship for Foreign Researchers" program is designed to invite excellent foreign researchers to Japan. This program is expected to use foreign researchers' knowledge and skills for the promotion of research in Japan, to foster research environments that allow researchers to vie with each other at the world level, and to establish international human resource networks and research networks with Japan as their core. It is important to allow many excellent foreign researchers to conduct research at universities and research institutions in Japan by using this system. For this purpose, it is necessary for host organizations to develop attractive research activities, as pointed out by some researchers. The idea of what is attractive may vary with the research area (refer to Part 1, Chapter 2, Section 1, 1, (1) 2)), but researchers are attracted by research environments where excellent researchers gather and provide plenty of intellectual stimulation and by advanced or large-scale research facilities that make it possible to conduct unique research that would be difficult to conduct at other facilities. The Japanese government is also promoting the "World Premier International Research Center Initiative" and "Large-Scale Academic Frontier Research Promotion." It is important to effectively combine these programs with research exchange programs. It is also important to use highly-talented foreign personnel to vitalize research conducted in Japan, for example, by making it easier for foreign researchers who have experience with research activities in Japan to continue working at other research institutions or companies in Japan.

2) Promotion of research through international cooperation projects

Research exchange is an essential factor in the promotion of international cooperation projects in S&T fields, such as with the International Thermonuclear Experimental Reactor (ITER), the International Space Station (ISS), the Integrated Ocean Drilling Program (IODP), and the Large Hadron Collider (LHC[1]). Let us take the example of ITER, a project for constructing a thermonuclear experimental reactor. The Japan Society of Plasma Science and Nuclear Fusion Research has been involved in the project since its design stage. Researchers who designed the reactor together enhanced their own research capabilities through discussion. They also directly experienced world-class research and a model research community. They are given opportunities to participate in an international research network and to develop an ability to play a key role in the network. IODP provides researchers with a similar opportunity as they are part of a team that conducts research on a research ship far away from shore.

1 The program uses a circular accelerator of the European Organization for Nuclear Research (CERN).

It should be noted that when researchers who teach at universities participate in medium-term or long-term joint research, they often have difficulties in combining research activities with their teaching loads, making it difficult to secure time for research. Their organizations need to provide support for them to deal with this problem.

In (2), 2) of this subsection, we have mentioned the example of grants for research conducted in collaboration among three or more organizations in Europe. There are similar programs in Japan: the e-ASIA joint research program, which provides support for international joint research based on individual researchers' participation, and the Science and Technology Research Partnership for Sustainable Development (SATREPS). The e-ASIA joint research program is a framework to promote joint research in East Asia with the aim of enhancing the R&D capabilities of the region by accelerating research exchanges. The countries whose researchers participate in the program will provide the same amount of grants as Japan's. SATREPS provides research funds, which is combined with the support from ODA, for the research jointly conducted with researchers in the regions specified by the government. In order to establish international research networks, it is necessary to strategically expand joint research between individual researchers from Japan and researchers from other countries while using the programs above. At that time, Marie Curie Actions, which is credited with strongly promoting the international mobility of researchers in Europe, will serve as a useful reference.

As shown in Figure 1-2-35, Japan has failed to join the global trend of international brain circulation. In order for Japanese researchers to promote world-class research and to achieve innovation based on it, it is necessary to develop environments that allow all highly-motivated researchers in Japan, especially young researchers, to be actively engaged in research at excellent research institutions throughout the world. It is also important to develop internationally attractive research environments where not only Japanese researchers, but also excellent foreign researchers, gather and pit their wits against each other, yet also cooperate with each other at research institutions throughout Japan. It is necessary to create the trend of brain circulation by promoting both the movement of researchers across borders and the development of attractive research environments within Japan. Developing many highly-skilled Japanese researchers who can play a key role in global research activities by keeping up with the trend of international brain circulation will help establish and strengthen international research networks, which in turn will improve the level of S&T in Japan. In order to develop such international research networks efficiently and effectively, it is important to promote strategic measures based on the characteristics of each research area.

4 Human Resource Development to Achieve Science, Technology and Innovation

The global society is rapidly changing, and the international competition regarding science, technology and innovation is getting stronger. Given these circumstances, the key to accomplishment of innovation is undoubtedly human resources; developing excellent human resources who will lead our country in the future is an important agenda. On the other hand, to create new values through innovation, it is necessary to utilize new ideas and mechanisms which are not just technical innovation. This goal should be achieved not only by researchers who perform S&T activities, but also, by a variety of people, including those who use the results of S&T. Consequently, the abilities required of human resources for science, technology and innovation are diverse in our present society, where the relationship between

S&T and the society is deepened and complicated.

In this section, we look at some of the efforts to develop human resources who can achieve science, technology and innovation or create new values, in order to find a clue as to what abilities are required of human resources for science, technology and innovation.

(1) Efforts to develop human resources for science, technology and innovation

1) d.school

The d.school, which is being held at Stanford University in the U.S. and in Potsdam, Germany, is an effort that has become the world's first design-thinking education (the term "design-thinking" is described later). Design thinking allows students to gain the abilities to cooperate with people from different fields and to act in a practical manner even when they face problems that cannot be solved easily. The school is intended to develop such human resources. The school is a hub where students from different backgrounds and various disciplines, such as medical science, engineering, management, law, cultural sciences, natural sciences and education, get together to create innovation. Students do not take lessons in the classroom, but form teams of up to ten people. They work on issues facing developing countries or issues in their own society—issues that private companies rarely address—in addition to conventional business issues that companies have. There are a variety of activities they participate in. For example, students hold a workshop and try to solve a problem about their subject for up to 12 weeks. This helps them better understand the nature of the subject and its background using methods such as field work, user interviews and clarification of issues. Then, they suggest an idea to solve the problem and create a prototype to achieve it. This visualized idea is then evaluated by them and by other people concerned. If there is any problem in this process, then they go back to try and better understand the subject.

Guidance is given by faculty members, specialists in various fields and facilitators[1]. Many things are taken into account, including the diversity of the students making up the team and the atmosphere and convenience of the place where the workshop is held, in order to focus on the teamwork among people from different disciplines. In some cases, an idea visualized at the workshop has been put into practical use by a company, or a venture business has been founded to realize an idea.

1 This generally refers to a person who controls the activities of a group, keeping the neutral position, and helping to maximize the results. They lead a workshop in participatory learning.

2) Olin College[1]

The Franklin W. Olin College of Engineering (hereinafter referred to as Olin College) in the U.S., is only around ten years old and is attracting wide attention. It presents a new form of engineering education, and has been described in the U.S. as "the most ambitious experiment in engineering education in several decades." Olin College is a very small college with around 80 students in each grade, but its education greatly differs from the traditional college education. Olin College holds high aspirations, saying that it "seeks to redefine engineering as a profession of innovation encompassing 1) the consideration of human and societal needs; 2) the creative design of engineering systems; and 3) the creation of value through entrepreneurial effort and philanthropy."

As a feature of its curriculum, the college fully implements active learning[2]; for example, by introducing project-based learning (PBL). In PBL, students form comprehensive, interdisciplinary teams that do not give too much weight to specialized knowledge and, instead, study real-world issues in about half of all their subjects. In addition, the college emphasizes interdisciplinary approach that deals with engineering for understandings of technical feasibility, arts, humanities and social sciences for understandings of people's desires, and business education for understandings of commercial feasibility. Based on this approach, the college intends to achieve creativity, innovation and design.

As the culminating experience of the Olin education, seniors have a compulsory subject called Senior Capstone Program in Engineering (SCOPE), an industry-university collaboration involving problem-solving learning. Students form multi-disciplinary teams, make plans on their own, and advance their projects to solve the problems presented by businesses. A close industry-university collaboration enables the projects to be carried out. Participating companies offer $50,000 to each project as funds for activities and the people responsible for the project at each company regularly contact and coordinate with the students. The students also appoint a project coordinator, a budget controller, a person in charge of safety and ethics, and a technical leader. They not only work on research and trial manufacturing in a particular field but also perform various activities, such as understanding needs, providing suggestions, practicing market research, examining technical studies, designing new products, improving existing products and analyzing commercial feasibilities-all with real-world problems as their subjects. Businesses bear a great burden, but they can lower their costs when compared with hiring engineers; these businesses also have opportunities to contact excellent students, which have sometimes led to their employing students as engineers in some cases.

These activities have long been said to be necessary but have not been carried out. Yet, Olin College has implemented them as a curriculum. That is why the college has received attention in the U.S.

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1 Created by MEXT, based on "How Olin College Realized and Succeeded in Engineering Education Reform," by Shinichi Kobayashi and others in "Engineering Education," 60(5), p18-23.

2 This is a general term for the teaching/learning method that introduces learners' active participation, instead of teachers' one-way lectures. The method is intended to develop general-purpose abilities, including cognitive, ethical and social abilities, culture, knowledge and experience, through learners' active learning. It also includes discovery learning, problem-solving learning, hands-on experiences and investigative learning. It is said that group discussion, debate and group work in the classroom are also effective methods of active learning. "Aiming for Quality Conversion of University Education to Create a Successful Future—Universities that develop abilities to continue life-long study and think independently (Report)," found in the glossary for the Central Council for Education on August 28, 2012.

3) i.school at the University of Tokyo

Following the efforts made in the U.S. and Germany, Japan too has developed education for innovation at the i.school, operated by the Center for Knowledge Structuring at the University of Tokyo.

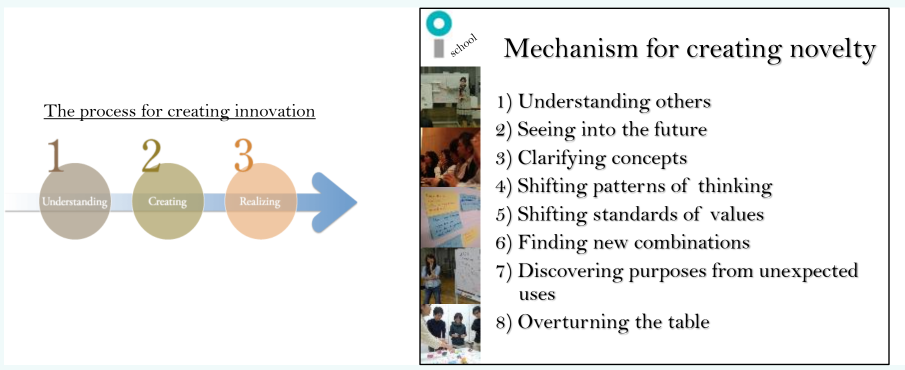
The educational programs at i.school consist of workshops for 20 to 30 participants. The workshops are held about six times a year. People who belong to any department of the University of Tokyo can apply for the workshops. Although most of the members are graduate students, undergraduate students who are eager to work may also be allowed to participate in them.

The targets of i.school are: 1) to be able to design an optimal workshop process when given a subject that requires creativity, 2) to acquire the thinking skills to create things that are novel and have an impact, and 3) to accumulate experiences of success in creating things that are novel and have an impact. The i.school emphasizes human-centered innovation that may be created through gaining insight into people's lives and values, rather than merely through technological innovation.

The process to create innovation is divided into three steps: 1) Understanding, 2) Creating and 3) Realizing. With these steps in mind, each workshop may focus on a particular step when designing the workshop process, or it may be designed so that students can experience all the three steps and understand the work flow (Figure 1-2-38).

The subjects vary, but those closely related to people's lives have been chosen. The school intends to have students experience a variety of workshops and learn how to design a workshop process. These kinds of workshops have been successful in developing abilities to create human-centered innovation around the world at d.school of the Stanford University, IDEO in the U.S., the Loyal College of Art in the U.K. and Aalto University in Finland. The i.school appeals to students in that they can experience these kinds of workshops at the University of Tokyo. The workshops have benefited participants and the i.school itself has learned, by analyzing the workshops, the design philosophy of the workshop processes and the purposes and effects of the incorporated process components. For example, a study on workshops held at i.school shows that there are eight types of mechanisms that are strategically embedded in the workshop processes so as to create novelty (Figure 1-2-38).

Figure 1-2-38 / The Process of Creating Innovation and the Mechanism for a Workshop Process to Create Novelty



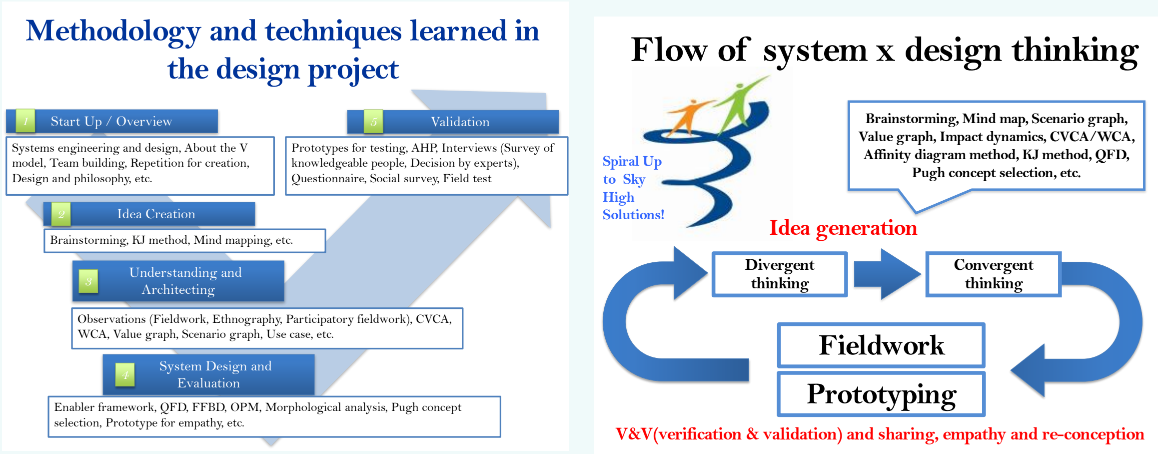
Source: Professor Hideyuki Horii at the University of Tokyo

4) SDM at Keio University

The Graduate School of System Design and Management at Keio University has an understanding that in order to solve complicated problems of our time, it is necessary to develop human resources for innovation who are able to break stereotypes and formulate a novel, whole concept in cooperation with a variety of stakeholders. For this purpose, the school provides education that enables people who have a particular specialty to have the ability to fully integrate multiple disciplines. Teachers at the school think that the ability required of human resources for innovation is a fusion of the ability to recognize an object as a system and the ability to collaborate with others in a team; thus, they have established the "System Design and Management" program (SDM program). The program compliments and combines "system thinking" and "design thinking." System thinking allows people to overlook a system, analyze the relation between the components of the system and construct them. Design thinking allows people to design creative solutions. In the SDM approach, design thinking regards one cycle as a flow of divergence, convergence, fieldwork and prototyping, and system thinking regards the same cycle as a V model. In this way, the approach is designed to allow the same step to be considered both in design thinking and in system thinking and to allow both ways of thinking to always be introduced at the same time. In addition, the program uses management education to implement and operate this approach (Figure 1-2-39).

The design project, which is at the core of teaching innovation education, consists of three phases. The first is the learning phase. Students learn the concept of the approach, methodology and techniques, not only from teachers at SDM but also from teachers at Stanford University and the Massachusetts Institute of Technology, as well as from designers who are actively involved in the front lines of the community. The second is the active learning phase, in which the concept methodology and the techniques learned during the first phase are applied without modifying them. The third is the project phase, in which students freely combine what they have learned and repeatedly use it to obtain good results. In the first and second phases, the workshop proceeds along the process designed by the teachers. In the third phase, however, the group of students design the process of the workshop themselves according to the situation. They are required to advance the project and to achieve results by making the process suitable for their situation and by freely going back and forth among the steps. Thus, the teaching takes the form of project-based learning. Multiple companies suggest real-world issues and students offer solutions for them. Through this education, the school is developing human resources who can involve the people around them and who can conduct activities that will actually result in innovation.

Figure 1-2-39 / How SDM at Keio University Understands System Thinking and Design Thinking



Source: Associate Professor Seiko Shirasaka at Keio University

5) QREC at Kyushu University

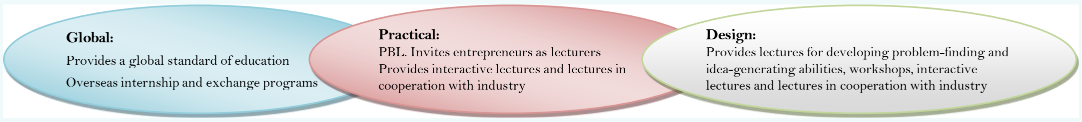
The Robert T. Huang Entrepreneurship Center of Kyushu University (QREC) is an entrepreneurship education and research center that was established as the result of a substantial donation made by Dr. Robert T. Huang, who has achieved significant success in the United States since graduating from Kyushu University. The goal of QREC is to foster future leaders (innovation talents, global talents) who have a sense of independence and ambition, a global point of view, and a willingness to actively create new values. QREC provides an entrepreneurial education in its broadest sense, by developing talented individuals who will challenge themselves to not only start new ventures but who will also work in a variety of other fields, such as supporting developing countries or starting social business.

QREC offers all undergraduates and graduates at Kyushu University to learn subjects (25 in 2013) that are categorized into three steps: Basic → Application → Practice, or Awareness/Motivation → Knowledge/Methodology → Integration. These subjects are intended to enable students to have an awareness of the issues, to learn knowledge and problem-solving techniques, to acquire problem-solving abilities by integrating knowledge, and to develop a willingness to take on challenges during the four-to-six year period they are at school. The school also provides various unique educational projects in addition to the regular subjects, aiming to serve as a comprehensive innovation education center.

As for educational methods, with an emphasis on Global, Practical Design, QREC offers not only classroom training but also case study exercises, workshops and PBLs in a team in order to provide participating students with opportunities to think, act and present on their own. Since all of the undergraduates and graduates at Kyushu University, including adult students, attend the program, students can meet people with diverse values and experience inspiring educational opportunities (Figure1-2-40).

Figure 1-2-40 / Overview of QREC at Kyushu University

[Basic concepts and features of QREC]



Systematic entrepreneurship education for integrated graduate/undergraduate schools: provides integrated and systematic entrepreneurship education for graduates and undergraduates for the first time in Japan
Fusion of entrepreneurship, MOT and management education: develops willingness and management ability to create innovative and concrete social values and results from research, technology, etc.
Practical, cooperation with industry: provides practical and interactive education using extensive discussion in addition to PBL and other subjects in cooperation with industry
Novelty and diversity: provides education that meets the needs of the time, such as businesses in emerging markets, social entrepreneurship and overseas internship programs
Global network: ensures and introduces optimal resources in collaboration with the world's major universities, including MIT
Global, diversity: provides international education by ensuring the active participation of foreign students and by providing places for overseas internship programs
Fusion of disciplines and collaboration inside universities: provides education in collaboration with other departments of the university, such as the Graduate School of Engineering and the Graduate School of Design
Open: provides extensive educational services in collaboration with other local universities and companies, mainly for students at Kyusyu University

[Examples of unique programs and projects at QREC]

QREP (Robert T. Huang Entrepreneurship Program of Kyushu University)
Students visit Silicon Valley in the U.S. for one week, attending lectures by a variety of noted instructors and exchanging opinions and information with Stanford University students and others. The program is designed to develop entrepreneurship and to improve their international awareness.

C&C(Challenge & Creation)
C&C is a university-wide effort designed to collect unique research projects planned by students, screen them, offer 500,000 yen to each of the eight selected projects so they can be completed within a year. At the final review, the highest award and a merit award are chosen, and the winners are honored by the president.

Entrepreneurship Seminar
The program invites guest lecturers who are actually demonstrating their entrepreneurship in the business world and it also provides lectures in an omnibus format. It aims to develop human resources who have a spirit of entrepreneurship and are willing to try new things.

Q-SHOP (The Kyudaisai Festival Business Startup Program)
The program offers students an opportunity to simulate a business startup at the Kyudaisai Festival. Participating students will become "entrepreneurs," use their stalls as companies, and go through the process of a business startup: developing a business plan → starting a new company → receiving investments from investors → buying in → preparing and operating their stalls → preparing financial statements → auditing → reporting to shareholders. This way, students can experience what it is like to manage a company.

AC (Academic Challenge)
AC is a research grant intended for graduates. Participating students carry out all the processes of research by themselves, from designing their research plan and searching for funding, to doing their research activities. The program aims to allow student to develop their "research management" skills through these practices.

Source: Professor Toru Tanigawa at Kyusyu University

6) Osaka University Cross-Boundary Innovation Program (Program for Leading Graduate Schools)

Osaka University has started the "Cross-Boundary Innovation Program,"[1] a five-year doctoral course educational program. In order to solve various problems arising in the modern world, we need to rapidly develop human resources for doctors who have the abilities to define problems, to create visions or models leading to a solution, and to carry out the necessary processes to put them into practice by using a broad range of professional knowledge and skills to have a wider view of them. They are thus required to reform our social system by going beyond the conventional interdisciplinary approaches. With this in mind, the basic policy of the program is developing abilities (diverse knowledge, genetic skills, and integration capability) to tackle problems in cooperation with many other people who have different areas of expertise, in addition to acquiring highly specialized knowledge through the traditional doctoral course of education. Above all, in order to solve complicated and difficult social problems, it is essential for us to cross various boundaries (disciplines, national borders, stereotypes, etc.) that restrict our thoughts and activities and to, instead, realize a "Cross-Boundary Innovation." Therefore, the program

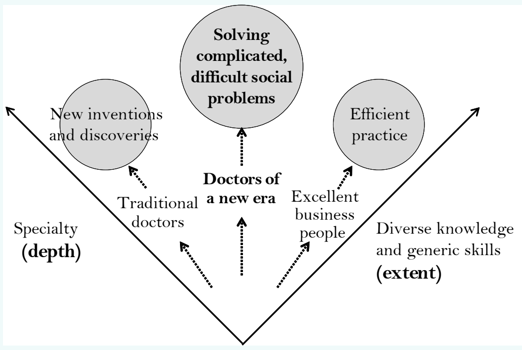
1 http://www.cbi.osaka-u.ac.jp

aims to develop doctors of a new era who will create what can only be created by crossing those boundaries, by having both highest specialty, and diverse knowledge and generic skills (Figure 1-2-41).

Students to be registered in the program will be selected from among all graduate students, who are majoring all disciplines such as humanities, sciences, engineering, at Osaka University. The curriculum is composed of professional training, which is used to develop expertise, and which is provided in the graduate course each student is enrolled in, and various program's own subjects: 1) the "Cross-Boundary Modular Learning," consisting of a) the subject group concerning knowledge and culture, intended to combine the humanities and sciences, (ethics, the understanding of history, the understanding of diverse cultures, the world of artifacts, scientific thinking, etc.) and b) the subject group concerning practical skills (communication, research skills, transferrable skills, design thinking, business skills, art, life skills, etc.), 2) the problem-finding field study, 3) laboratory rotation across the boundary between the humanities and science, 4) workshops and projects to solve social problems, 5) a long-term practical internship program ranging from three months to a year and other programs. These diverse subjects make the program a full-scale sub-major.

The course work particularly emphasizes an objective of making students aware of other points of view; for example, by becoming aware of the characteristics of developed countries by visiting developing countries in addition to developed countries. In addition, by aiming to lead students to cross many boundaries with such awareness, the program provides active learning mainly by discussion and workshops. Furthermore, based on this awareness, the program introduces PBL (Project-Based Learning) for challenging to solve social problems, and includes various activities planned by the students themselves. These subjects as a whole allow the students to acquire framework or models for cross-boundary innovation by fully using a broad range of knowledge, culture and practical skills along with their expertise as its core.

Figure 1-2-41 / Conceptual Diagram of Human Resource Development at the Osaka University Cross-Boundary Innovation Program



Source: Osaka University

Behind the course work described above, the "Cross-Boundary COMPASS (Components Of Mastery, Performance, Attitude, and Skill Sets)," has been established as a guideline for the qualities and skills to be acquired. It consists of the following six key drivers: "Cross-Boundary Exploring Power," which serves as the basis of everything, "Cross-Boundary Creative Thinking Power" and "Cross-Boundary Implementing Power," which serve as the general core of knowledge and skills, "Cross-Boundary Leading Power," which serves for embodying and developing organizations and "Cross-Boundary Networking Power," which enhances communication and cooperation with various actors, and "Cross-Boundary Challenging Power," which is shaped into the power of excellent humanity by the integration of the others. Using this evaluation at respective phases of education, the program ensures that enrolled students will become global leaders.

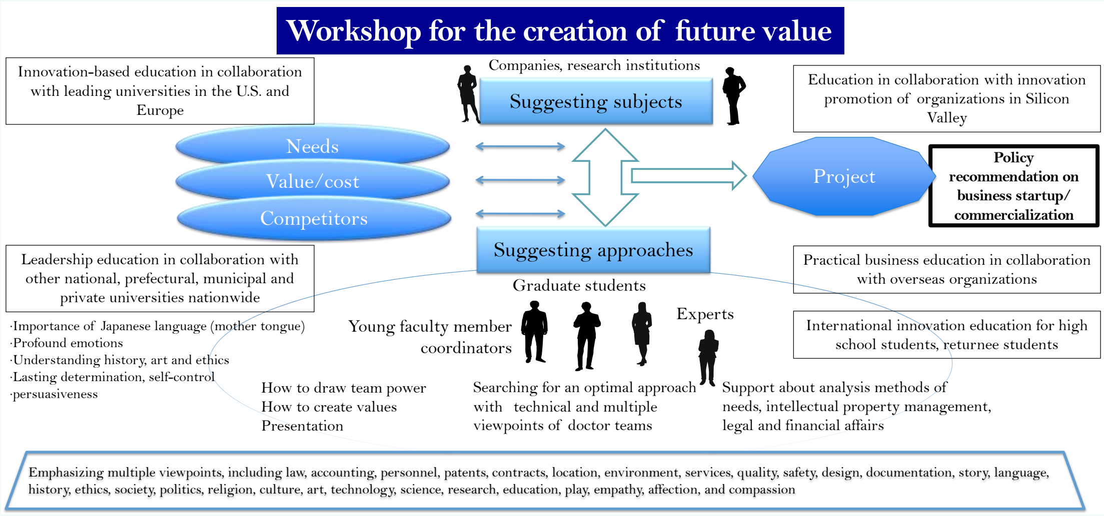
7) The Innovation Advancement Organization at the Tokyo University of Agriculture and Technology (A Model Project of Human Resource Development for the Advanced Research of a Needs-Creation Practice Type)

The Tokyo University of Agriculture and Technology has established an organization for the promotion of innovation and is actively promoting the "Model Project of Human Resource Development for the Advanced Research of a Needs-Creation Practice Type" in collaboration with industry and government. The project focuses on fostering leaders in innovation. The organization has a clear idea about who is the innovation leader and who has been making efforts with an understanding that the issue is very important in determining the future state of university education and for fostering young people who will lead Japan and the world in the future and that its importance should be recognized by all universities, their affiliates and those who receive training.

It is important to broadly define innovation as the skill "to reform oneself, to touch others' hearts and to change society for the better." Specifically, it is difficult to reform oneself or to attract others or to get others to understand and sympathize with a new value that he or she created. However, these processes are very important when suggesting to society a new value, such as a new technology or a new social system, and when trying to get society to accept it and, thus, change for the better. What is the innovation leader is expected to do is to have strict self-control, intelligence and persuasiveness. The basis of persuasiveness is the ability to use the Japanese language and profound emotions in order to empathize with others, that is, to have broad-mindedness. These qualities of the innovation leader are also required of doctoral students who are trying to be researchers. For example, if one tries to continuously present excellent academic papers, then one will naturally need some qualities other than just a profound knowledge, or skills and experience in one's own discipline. An academic paper is not just a report on the results of an experiment or research; it requires concreteness, reliability, unpredictability, a clear story based on one's idea about the subject being studied, and, especially, the ability to persuade others and make them believe in the cause.

Based on these ideas, the Innovation Advancement Organization has developed a systematic educational program that centers on the "workshop for creation of future value" and that crosses organizations and disciplines. The organization is practicing activities to foster innovation leaders in collaboration with many other people (Figure 1-2-42). These activities are designed to emphasize the requirement of having the ability to connect expertise with society; to define internationalism, team power, and collaboration between organizations; to establish mutual understanding as key elements; and to focus on developing human resources who will be able to create future values and who will lead the process until society has realized new values.

Figure 1-2-42 / Overview of the Workshop for the Creation of Future Value at the Tokyo University of Agriculture and Technology



Source: Professor Kazuhiro Chiba at Tokyo University of Agriculture and Technology

Column 1-7

Society of Innovation Education

There is a growing interest in innovation education that develops the ability to produce products, services business models and social systems that are innovative and that would have a great impact on society. More and more universities and companies are practicing innovation education.

Given these circumstances, the Society of Innovation Education was established in February 2013, and is intended to promote research activities to improve the quality of innovation education programs. Major universities that provide advanced innovation education programs have joined society to present the results of their activities and research and to learn from each other. These organizations include SDM at Keio University, the Design School at Kyoto University, the Tokyo Institute of Technology, the Graduate School of Design at Kyusyu University, QREC at Kyusyu University, SSD at Tohoku University, and the i.school at the University of Tokyo.

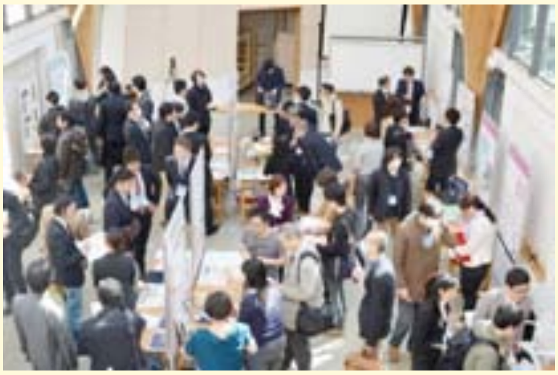
At the first annual meeting, held in March 2013, to kickoff its workshop on the first day, the i.school at the University of Tokyo presented its workshop, which is usually only reserved for students at the University of Tokyo. With the theme of improving campus life, they made a presentation about "the creation of more exciting, convenient and innovative services and activities by thinking outside the box" and provided the audience an experience of the human-centered innovation process studied at the i.school.

On the second day of the annual meeting, more than twenty elaborate research presentations and lectures were given around the theme of "What the Society of Innovation Education will aim at." At a panel discussion, participants agreed that society should be designed to provide opportunities for creative and intellectual presentations that are free from the frameworks and operation methods of existing societies.

The meeting was held with more than 200 participants from a variety of organizations, mainly from universities, but also from educational NPOs, local governments and private companies. Collaboration among many people is the key element for innovation education. It is hoped that society will play an active role in developing innovation talents.

Workshop

Research presentation



Panel discussion

Source: Professor Hideyuki Horii at the University of Tokyo

2) Abilities expected of science, technology and innovation talents

We have looked at a variety of efforts to develop human resources. There are various efforts aiming at developing diverse abilities, and many efforts other than those introduced here have been made. At the moment, however, there are no standards for the abilities that science, technology and innovation talents should have or for the methods of development. The abilities required will change according to the changes of social situations, and human resource development will become better as the development methods become more sophisticated and new methods are devised.

On the other hand, the efforts being made today, as mentioned above, have a common understanding. For example, they aim to solve problems that span a wide range of disciplines, going beyond a specialized field and putting solutions into practice. For this purpose, these efforts are all intended to result in the acquisition of advanced specialized abilities, to understand the various factors in solving problems (such as human desire, business and social problems), to be able to find problems that have yet to come to the surface and to set subjects based on these understandings, and to work out creative solutions together with many other people from diverse disciplines.

In order to develop such abilities, for example, the efforts should focus on recognizing and setting issues, including understanding the economy, society and humans; they should be intended to go beyond disciplines and integrate them; they should be practical, such as collaborating with people or companies having knowledge in different fields; and, therefore, they should be active-learning-oriented, using not just classroom training but also workshops. These are the points that all these efforts have in common.

One of these efforts is the education based on design thinking, which has been drawing attention lately. It is said that the name of design thinking was first used by IDEO in the U.S. There are many descriptions of the word, but the basis of design thinking is utilizing a method of understanding and solving problems by using the senses and skills of designers who consider people's feelings when creating products. Design thinking is described as a basic method with three combined elements: science and technology, business, and human-centered values[1] that take into account an actual or latent evaluation made by consumers or users, not by researchers or companies. Design thinking is divided into six steps: 1) understanding, 2) observing, 3) defining point of view, 4) ideation, 5) building prototypes and 6) testing. Practitioners are expected to go back and forth among the steps (not to proceed in order) to better understand the problem, to grasp its nature, and to solve the problem (Figure 1-2-43).

Design thinking requires one to not only think about the problem but also the practice. Therefore, one needs to substantiate ideas by building a prototype[2], using brainstorming, observing ethnography[3] as it is used in cultural anthropology, and by implementing other techniques as well as by logical thinking and hypothesis-testing thinking, which have been traditionally used to solve problems. Then, one must analyze the results and use them for further examination.

In addition, one needs to have the ability of teamwork that makes it possible to collaborate with people from entirely different disciplines and to better understand others. Thus, a team is formed with people from different disciplines working together on real-world issues. This is because more ideas are produced

1 The word is human-centered in English. This refers to an idea or a process that focuses on users. For example, when some product is produced and sold, the product should be designed so as to maximize the value or happiness users will receive, not to meet the convenience of the manufacturer or the seller, such as cheaper material costs or transportation costs.

2 This refers to a trial model such as a product. As a means of making a prototype, a "3D printer" is used.

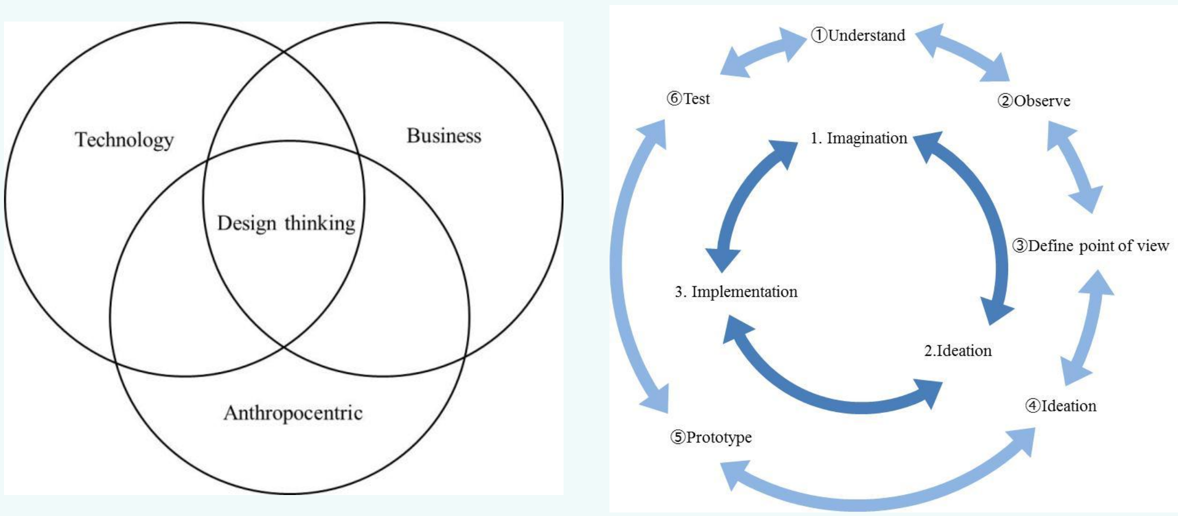
3 This refers to the methods of studying and recording the behavioral patterns of groups or societies through fieldwork.

through the collaboration of diverse people than by an expert individual alone; thus, these efforts are not intended to nurture individual expertise.

Educational programs based on design thinking are provided at d.school mentioned above, at Aalto University in Finland and at other universities in Europe and Australia. In Asia, Singapore in particular has been promoting design thinking education as a national commitment. Other Asian countries, such as Korea, China, India and Malaysia, have also been providing design thinking education in recent years.

This way of thinking and this type of education has probably become widespread because it is no longer true that learning the most advanced knowledge and technology of a particular industry will automatically result in the creation of excellent values. This is a way of developing human resources that are appropriate for the current situation of the economy and of society.

Figure 1-2-43 / Three Design Cognition Elements and Design Cognition Stages



Source: National Institute of Science and Technology Policy: Toshiaki Kurokawa's Design Thinking Education in University and Graduate School (2012)

So far, we have looked at some efforts that aim to solve problems. It can be said from a different angle that it is necessary to develop not only the abilities required for R&D activities but also the general-purpose skills that can be used in various areas throughout our society. On the other hand, expectation is growing in Japan and many other countries that people who have a doctoral degree will play a big role not only as researchers but also as core innovation talents who possess expertise, discover problems, plan projects for solving those problems, and even lead the project. However, these countries are also aware that their expertise prevents them from working in broader areas of the society. Considered to be general-purpose skills necessary for solving this issue, "transferable skills[1]" are drawing attention in European countries. Transferable skills are the skills that doctoral students should acquire in order to deal with project-type research or new types of research, such as interdisciplinary research, when they work in a team at a university. These skills also allow them to play an active part in a company

1 A report, "Research Careers in Europe Landscape and Horizons" issued by the European Science Foundation defines the word as follows: "Transferable skills are skills learned in one context (for example research) that are useful in another (for example future employment, whether that is in research, business etc.). They enable subject- and research-related skills to be applied and developed effectively."

or in other areas outside of academia, so these skills are important to ensure a wider range of job options.

The U.K. started a study on this issue in the 1990s. The Research Councils UK organized the skills that doctors and researchers should acquire and published the "Joint Statement of Skills Training Requirements of Research Postgraduates (JSS)" in 2001. The skills were classified into seven types: "Research Skills and Techniques," "Research Environment," "Research Management," "Personal Effectiveness," "Communication skills," "Networking and Team-working," and "Career Management." The classification was the framework of professional skills that graduate students and post doctors should acquire. Based on the classification of the skills, the U.K. Grad Program started a grant project for funding the costs of training and the development of training programs in 2002 with the aid of Research Councils UK. In 2008, in place of the U.K. Grad Program, Research Councils UK helped establish the Vitae network, which has advanced JSS and has introduced the framework of the "Researcher Development Statement," which includes education for post doctorates, and the "Researcher Development Framework," classified under it (Figure 1-2-44). Based on those frameworks, the education of graduate students and post doctorates has been improved.

Table1-2-44 / Vitae "Researcher Development Framework"

Domain	Sub-domain	Sub-domain summary
A. Knowledge and intellectual abilities	(A1) Knowledge base	• Research methods: theoretical knowledge • Information seeking etc.
	(A2) Cognitive abilities	• Analyzing • Critical thinking • Problem solving, etc.
	(A3) Creativity	• Inquiring mind • Innovation, etc.
B. Personal effectiveness	(B1) Personal qualities	• Self-confidence • Responsibility, etc.
	(B2) Self-management	• Preparation and prioritization • Work-life balance • Time management, etc.
	(B3) Professional and career development	• Career management • Continuing professional development, etc.
C. Research governance and organization	(C1) Professional conduct	• Health and safety • Ethics, principles and sustainability • IPR and copyright, etc.
	(C2) Research management	• Research strategy • Risk management, etc.
	(C3) Finance, funding and resources	• Financial management • Funding generation, etc.
D. Engagement, influence and impact	(D1) Working with others	• Teamworking • Leadership, etc.
	(D2) Communication and dissemination	• Communication methods • Publication, etc.
	(D3) Engagement and impact	• Public engagement • Enterprise, etc.

Extracted from RDF proposed by Vitae.

Source: MEXT documents based on Yasunori Yamanouchi and Chie Nakagawa's U.K. Transferable Skills Training Efforts: Hints for Japan's Science and Technology Professional Development, S&T Communication, 12: 92-107, 2012.

On the other hand, when we look at other countries, there is no consensus on how to view these specific skills, and the methods to acquire these abilities are still developing. For example, the European Science Foundation says that transferable skills may be acquired through training or work experience. The European University Association points out that it is necessary for doctoral courses in different disciplines to get together and provide opportunities for a variety of trainings, so that students can develop creative power in an interdisciplinary environment. In some cases, in other countries, work experience or courses to acquire communication skills or leadership skills are provided. In either case, in addition to lectures, participatory learning and training in a group of people from diverse backgrounds are emphasized in order to acquire transferable skills.

The issue of acquiring general-purpose skills that are also useful to society is also recognized as a general issue in university education. Many countries are making various efforts, with some countries naming the skills differently, such as labeling them as generic skills. Assessment and Teaching of 21st Century Skills (ATC21S), an international joint project developed by a private company in collaboration with some governments and institutions, advocates "21st Century Skills" consisting of four categories: ways of thinking, ways of working, tools for working and ways of living in the world.

So far, we have described for a shared understanding in regard to the development of science, technology and innovation talents. None of the efforts assures that they will become science, technology and innovation talents simply as a result of employing a specific style of education or special techniques, or because of student acquisition of knowledge. There is no solution to how science, technology and innovation talents can be developed. In Instructors strive to grasp the knowledge and abilities required of human resources who can play an important role in economic society and they try to offer them to students on a trial-and-error basis.

In the future, educational institutions at home and abroad will need to step up their efforts to develop science, technology and innovation talents. Taking account of the recent social request for innovation, the basic principle is to develop human resources who have freedom and a broad range of ideas, regardless of their disciplines, take leadership aiming at solving social problems, and think strategically to work out creative solutions in order to overcome social challenges and reform society.