



Research on the Nurturing and Maintaining of STI talent in Singapore (Addendum): The Driving Forces behind the Progress at NUS and NTU

February 2024

Established in April 2021, the Asia and Pacific Research Center (APRC) of the Japan Science and Technology Agency (JST) aims to contribute to building a foundation for innovation in Japan by expanding and deepening science and technology cooperation in the Asia-Pacific region based on the three pillars of research, information dissemination, and networking.

This report is compiled as part of a research that surveyed and analyzed science and technology innovation policies, research and development trends, and associated economic and social circumstances in the Asia-Pacific region. It is being made public on the APRC website and portal site to enable wide use by policymakers, associated researchers, and people with a strong interest in collaborating with the Asia-Pacific region; please see the websites below for more details.

APRC website:

<https://www.jst.go.jp/aprc/en/index.html>



Research Report (Japanese website):

<https://spap.jst.go.jp/investigation/report.html>



Summary

In many indicators, Singapore has shown scientific and technological capabilities that are equal to or better than those of other developed countries, and the National University of Singapore (NUS) and Nanyang Technological University (NTU) have emerged as top universities in Asia and the Pacific. In order to clarify the reasons for the rapid progress of both universities and the background and aims of their medium-term plans from the perspective of nurturing and maintaining human resources, this report conducted interviews to obtain the views of policy authorities and receptions at research sites. Through the results, it became clear that Singapore's bold and systemic national initiatives were behind its progress. At the end of the 20th century, the government announced a policy to reform both universities to focus on research, set aside funds in Singapore's medium-term plans, and then steadily allocated the funds to encourage implementation of this policy. The medium-term plan also designated strategic priority areas and sought to rapidly raise the level of Singapore's research and development capabilities by inviting top foreign talent. Going forward, from the perspective of improving autonomous and sustainable research and development capabilities, there is also a visible trend of the government focusing on nurturing and maintaining domestic human resources. The rich and unparalleled internationality, as seen in Singapore's extremely high percentage of foreign researchers, is exactly what the research environment in Japan is severely lacking, and Singapore's case can be considered to be highly instructive.

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1 Introduction

1.1 Objectives and Targets

The JST Asia and Pacific Research Center promotes science and technology cooperation with major countries in the Asia-Pacific region, and conducted the “Research on the Nurturing and Maintaining STI Talent in Singapore (hereinafter referred to as the “Talent Report 2022”)” in FY2022 in order to clarify matters that should be referred to in promoting nurturing and maintaining of Japan’s science and technology human resources. The report was primarily conducted via desktop research, but the following items were difficult to fully understand using only this method:

- Reasons for why NUS and NTU have rapidly become the top research universities in the Asia-Pacific region
- Background and aims for formulating a national strategy to improve scientific research capabilities
- Perceptions of Singapore’s measures for nurturing and maintaining human resources from the perspective of research sites, and opinions about Japan

As such, it was decided that these matters would be clarified through on-site surveys and that they would be published as a supplemental report to the Talent Report 2022.

1.2 Methodology

While this report primarily conducted in-person interviews via on-site visits, remote interviews with some participants were also conducted via online meetings.

The questions for policymakers and university executives were based on the facts as investigated in the Talent Report 2022, and, in line with the three report objectives listed above, these interviews were aimed to clarify and understand the actual, on-the-ground situation that is difficult to fully understand through desktop research.

The same questions as those mentioned above were also put to researchers working at local universities and research institutes, and they were asked to respond with laboratory-level views and responses or with the university’s views. This was done because, by adding the views of research sites to the views of the authorities, it would be possible to evaluate Singapore’s efforts objectively and from multiple perspectives.

1.3 Report Visits

The names, affiliations, and biographies of the individuals visited are as follows (affiliations and positions are as of the time of the visit).

Beh Kian Teik, CEO, National Research Foundation, Singapore (NRF)

After majoring in electrical engineering at the University of Illinois Urbana-Champaign and the University of California graduate school, Beh Kian Teik worked at the Singapore Economic Development Board (EDB) for more than 22 years. He is involved in industry-academia collaboration and is responsible for supporting the startups of many entrepreneurs. Since July 2020 he has been appointed as the NRF’s Deputy Chief Executive Officer, and is involved in the formulation, evaluation, and implementation of the Research, Innovation and Enterprise (RIE) five-year plans. He assumed his current position from August 2022, when he succeeded Low Teck Seng.



Aaron Thean, Deputy President (Academic Affairs) and Provost, NUS

Aaron Thean majored in microelectronics, and also serves as the Director of the National Research Foundation’s SHINE centre, a next-generation microelectronics research facility, and the A*STAR SIMTech–NUS Joint Laboratory for Large-Area Flexible Hybrid Electronics. After 20 years of research and development work at major semiconductor technology companies in the United States and Europe, including IBM, Qualcomm CDMA Technologies, and Motorola, he transferred to NUS in 2016 under Singapore’s talent recall program. At NUS he served as the Dean of the Faculty of Engineering from 2019, and as the Dean of the College of Design and Engineering from 2022 to 2023.



Timothy J. White, Vice President (International Engagement), NTU

Timothy White received his PhD from the Australian National University in mineral chemistry and crystallography, and has spent over 30 years designing and demonstrating materials for nuclear power, environmental, superconductivity, ionic conduction, and hydrogen storage applications. He assumed his current position after serving as an associate professor and then professor at NTU’s School of Materials Science and Engineering, and as Co-Director of the Energy Research Institute @ NTU (ERI@N). He has held senior positions at ANU and the Institute of Environmental Science and Engineering (Singapore), and was seconded to the Institute for Transuranium Elements (Germany) and the Japan Atomic Energy Agency (JAEA).



Sato Hirotaka, Professor, School of Mechanical & Aerospace Engineering, NTU

Sato Hirotaka completed the doctoral course at the Department of Applied Chemistry in the School of Advanced Science and Engineering at Waseda University. After working as a researcher at the University of Michigan and at the University of California, Berkeley, he became an assistant professor in the School of Mechanical & Aerospace Engineering at NTU in 2011, an associate professor in 2018, and his current position in 2022.



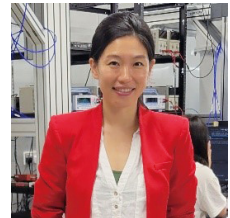
Eda Goki, Associate Professor, NUS Centre for Advanced 2D Materials (CA2DM)

Eda Goki graduated from the Department of Science in the College of Liberal Arts at International Christian University. He received his master's degree from Worcester Polytechnic Institute, his PhD from Rutgers University, and served as a researcher at Imperial College London, before assuming his current position in 2011.



Yvonne Y. Gao, Associate Professor, NUS Centre for Quantum Technologies

After graduating from high school, Yvonne Gao moved to England and received her bachelor's degree in physics from Oxford University and then a PhD in physics from Yale University. In 2020 while working at the A*STAR Institute of Materials Research and Engineering (IMRE), she was selected as one of the “Innovators Under 35” by the MIT Technology Review and as one of “The Asian Scientist 100” by Asian Scientist Magazine.



Inoue Kyota, Second Secretary, Embassy of Japan in Singapore

* In addition to the above individuals, an in-person interview was conducted with one researcher working at A*STAR.

2 The Rise of Singapore's Top Universities and the Reasons for their Ascent

In the 2023 world university rankings, NUS and NTU rapidly increased their position in terms of scientific research strength, with NUS being ranked 11th by QS and 19th by THE, and NTU being ranked 19th by QS and 36th by THE. In particular, as mentioned in Talent Report 2022, NUS has maintained the highest ranking in the Asia-Pacific region for five consecutive years since 2018 in the QS university rankings.

In general, English-speaking universities tend to dominate the top levels of university world rankings. However, why Singaporean universities have achieved in the top position in the English-speaking areas of the Asia-Pacific region, beating out larger economies such as Australia and India? Based on interviews with NUS and NTU executives, this section explores the circumstances surrounding and secrets behind the rapid rise to prominence of both schools.

2.1 The Rapid Progress of NUS and NTU

Why have NUS and NTU become top universities in the Asia-Pacific region? A shared reason can be attributed to the reforms made from the end of the 20th century to the beginning of the 21st century, when they shifted from being education-oriented universities to being research-oriented universities.

As has already been seen in the Talent Report 2022, NUS has established eight affiliated research institutes and six Centres of Excellence (COE) since the beginning of the 21st century, and is strengthening its ties with major cities around the world, including in the United States, China, India, and Sweden.¹ Foreign researchers accounted for only approx. 10% of the total number of NUS researchers in the 1980s, but this increased to 39% in 1997 and to more than half between 2007 to 2012. A series of hub institutions with industry, such as the Technology Transfer and Innovation office (established in 1995), NUS Enterprise (established in 2000), and entrepreneurship centers, were also establish, and the number of national patent applications has doubled in the 10 years since 2012 (Talent Report 2022, Figure 2-13).

Furthermore, according to Vice President White, by 2014 NTU had transformed itself from a college with only an engineering and business faculty into a comprehensive university by establishing new faculties for science, medicine, and the humanities and social sciences.

The following factors can be cited as reasons for both universities' remarkable development as research-oriented universities.

- (1) Clear goals set by the government and universities to “develop from teaching universities to world-class research universities.”
- (2) Implementing major university reforms in terms of appointment and evaluation methods for human resources in order to shift from being education-centered to being research-centered

¹ In the late 1990s, 12 experts from industry, academia, and government visited the United States, United Kingdom, Sweden, and Israel to inspect their undergraduate admissions systems. Tan, J. (1999) “Recent Developments in Higher Education in Singapore.” *International Higher Education*, (14). <https://doi.org/10.6017/ihe.1999.14.6463> .

- (3) Steady and significant increases in university research funds by the government
- (4) Strategic research initiatives by establishing key science and technology fields for the country and universities
- (5) Promoting international collaborations by acquiring outstanding foreign human resources and domestic collaborations by nurturing domestic human resources
- (6) Strengthening industry-academia collaboration, both on and off campus

In Singapore, the government and universities have cooperated to carry out large-scale university reforms without hesitation despite numerous difficulties and conflicts, including a large-scale replacement of faculty members to achieve these goals, and have strongly promoted the six measures listed above. The authors believe that NUS and NTU were formed into world-class universities by promoting measures (2) to (6) through government-university partnership, in line with the goal (1) set by the government.

In the following sections, we will see how these six measures have been implemented in Singapore.

2.2 Clear Goal Setting by the Government and Universities

Singapore's share of the world's GDP has quadrupled over the past 40 years, and the country has come to rival developed countries as a hub for growth in Asia, particularly in the financial sector. With this economic growth, the focus has been on further strengthening research and development and building capacity for innovation to stimulate even more sustainable growth.

In 1997, then Prime Minister Goh Chok Tong announced a policy goal for NUS, NTU, and the newly reorganized Singapore Management University (formerly the Singapore Management Institute) of “developing the three universities from education-oriented universities to world-class research-oriented universities” in order to further develop Singapore.² In 2006, NUS and NTU were made into “autonomous universities” with greater management autonomy in order to compete with universities around the world and to provide a unique education.³ This made it possible for them to make discretionary decisions regarding the direction of research and development, as well as for investments in human resources and equipment for this direction, thereby accelerating their shift to research universities.

2.3 Specific University Reforms and Government Support for Becoming World-Class Research Universities

2.3.1 Reforming the Appointment and Evaluation Methods for Science and Technology Human Resources

In order to shift the evaluation focus of faculty members' performance from education to research, both universities

² Singapore Government, “NUS, NTU, SMU to Become Autonomous Universities,” April 12, 2005. Currently, there are six autonomous universities, including the three mentioned above. <https://www.moe.gov.sg/post-secondary/overview/autonomous-universities>

³ Wong, P.-K., Y.-P. Ho, and A. Singh (2007). “Towards an “Entrepreneurial University” Model to Support Knowledge-Based Economic Development: The Case of the National University of Singapore,” *World Development*, 35(6), p.954.

implemented groundbreaking university reforms that were fraught with difficulties. In other words, domestic faculty whose research performance was poor were replaced, and foreign scholars were actively appointed. Efforts were also made to secure students who would lead the next generation of scientific research. In order to foster its own citizens, the number of international undergraduate students was limited to a certain percentage (15%) or less,⁴ but, based on the idea of non-discrimination between Singaporean citizens and foreign nationals in R&D, more than 50% of graduate students are international students.

Also, a strict tenure-track system was introduced as part of the university reforms. Obtaining tenure provides a faculty member with greater research autonomy and the right to hire the personnel necessary to achieve their research.

NUS adopted a tenure-track system in 2001 as part of the university reforms. According to associate professor Yusuke Toyama (Deputy Director, Mechanobiology Institute, Department of Biological Sciences),⁵ during a typical tenure track term of seven years candidates must accumulate results and achievements primarily in education and research, submit review documents at the end of the sixth year, and then, after one year of review, a decision is made on whether or not to appoint them as faculty without a fixed term. Academic affairs and committee work is largely exempted, but tenured faculty without a fixed term and administrative staff work together to support an environment in which young researchers can focus on their next career. This kind of organized career development system fosters cooperative and practical faculty who can also handle academic affairs.

According to Vice President White, in order to obtain tenure at NTU, candidates must meet strict standards along three axes of evaluation during a seven-year term: research, education, and social contributions. Grants of tenure are deliberated upon by the Promotion and Tenure Committee, which is chaired by the university's Provost. Of the ten individuals providing recommendations, three must be co-authors with the applicant, and seven must be unaffiliated independent researchers. In addition to letters of recommendation, the applicant must also prepare a large number of other documents, including research and teaching history, student evaluations of the applicant's teaching, and citation reports of the applicant's achievements as extracted from library services. Even so, the conversion rate to tenure is said to be around 65%, meaning that one out of every three or four applicants will not receive tenure.

Furthermore, according to Vice President White, in order to accelerate its transition to a research university, in the 2010s NTU utilized such evaluations through the tenure-track system and implemented a series of reforms (1) to dismiss approximately 250 faculty members who were inactive in research activities in order to create room for securing more talented science and technology personnel, and (2) to secure approximately 60 to 70% of its human resources by recruiting them from external organizations (other domestic universities and foreign universities).

While the evaluation process has become more rigorous, a system has also been established that allows individuals with outstanding expertise to begin autonomous research from the early stages of their careers. For example, the introduction of the Presidential Young Professorship at NUS establishes (1) A tenure-track position

⁴ According to an official announcement by then Minister for Education Heng Swee Keat, the proportion of international students would be lowered from 18% to 15% in order to free up places for Singaporean students. "University World news" August 21, 2011 <https://www.universityworldnews.com/post.php?story=20110819174750326>

⁵ RA Council 7th Annual Conference Planning Session A-3, "Considering Ways to Support Young Researchers," September 15, 2021. The following transcript of the lecture was referenced from the website of the Osaka University Office of Management and Planning. https://www.ura.osaka-u.ac.jp/images/vol74_ambai_transcript_v2.1.pdf#page=18

with an attractive salary package as an assistant professor at NUS, (2) Up to \$1 million SGD (108 million JPY, 1SGD=108JPY) in a start-up research grant attached to (1) and the discretionary authority to hire PhD students as researchers, (3) An award of \$250,000 SGD (27 million JPY) in white space funding (from the NRF five-year plans; described below) which can be flexibly used, and (4) An opportunity to compete for an NRF Fellowship.⁶

2.3.2 Steady Increases in Government Funding for University Research

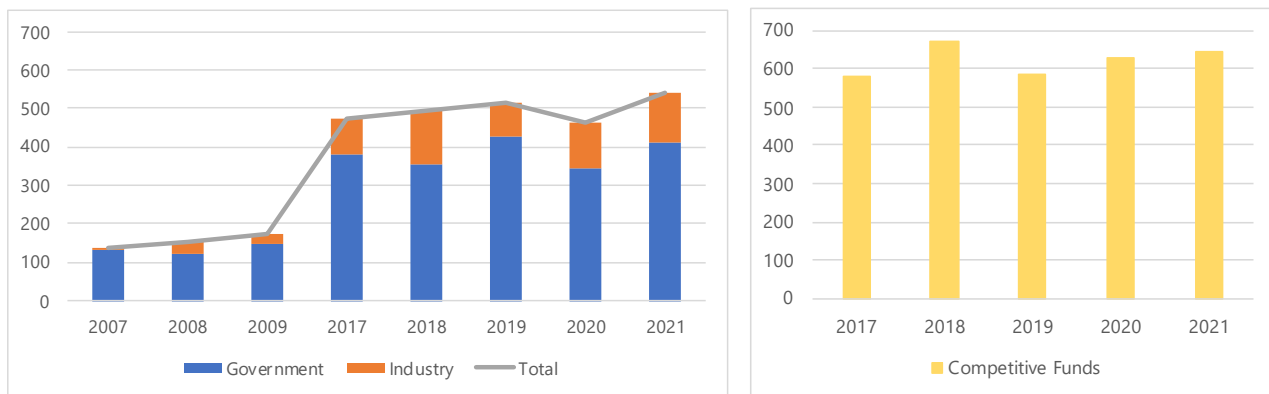


Figure 2-1: Changes in Own Funds and Competitive Funds Contributed to NTU Over Time
(Units: \$10,000 SGD) Source: NTU Annual Report 2010, p.97 and NTU at a Glance 2023, p.18.

Each university’s research budget is made up of both its own funds and competitive funds, with steady increases seen in both the amount of funds and systemic allocations being made in accordance with the national five-year plan. As an example, Figure 2-1 shows budget trends for NTU. In the past ten years, NTU’s own budget has increased by approximately 2.5 times, and, although data for the prior ten years is not available, competitive funds have remained at around \$570 million SGD for the last five years. This is high compared to the roughly 1.4 times increase in research and development expenditures in Singapore as a whole during the same period, and as such it can be said that NTU’s own funds have notably and significantly increased.

This increase was made possible by the rapid expansion of Singapore’s GDP, mainly due to increased foreign direct investment, rather than through the university’s own measures, so a great deal depends on factors outside of academia.

2.3.3 Establishment of Strategic Science and Technology Fields

Singapore, which has limited physical and human resources compared to other developed countries, promotes research and development based on the government’s five-year plans (the five-year plans are formulated by the Research, Innovation and Enterprise Council (with the NRF as the secretariat) in the Prime Minister’s Office, as shown in section 3. Competitive research funds (mentioned in the previous section and obtained by universities and public research institutions) are provided based on this government plan. On the other hand, each university understands the direction of the national plan and, independently of the national plan, they define their own strategic

⁶ Refer to the overview on the NUS website. <https://www.nus.edu.sg/careers/NUS-Presidential-Young-Professorship.pdf>

science and technology fields and engage in focused promotion of them. It is believed that universities' own funds in their respective budgets (mentioned in the previous section and not including competitive funds) are primarily used to promote strategic science and technology fields that the university has independently determined.

At NUS, strategic research fields are established through consultations between the university's executive department and the undergraduate departments, and research institutes targeting cutting-edge technology fields are also flexibly established. Currently, the university's key areas include aging; regional studies; bioscience and bridging medicine; finance and risk management; oceanography; materials science; smart nation; and sustainability and cities; as well as the humanities and social sciences.⁷ NUS has also continued to focus on cutting-edge technologies, such as through the establishment of the Centre for Quantum Technologies (CQT) as a Centre of Excellence for quantum science research.⁸ Deputy President Thean said, "I believe that the role of universities is to maintain researchers' motivation and to create diversity in research themes. As such, in principle we do not manage professors' research themes. However, we work with the departments and faculty to identify strategic research themes, noting that the aim is to hire world-class researchers in those fields and to then provide them with funding to enable them to conduct the best research possible."

This same trend can also be seen at NTU. According to Vice President White, NTU has announced its own five-year research strategy since 2010 and utilizes it to secure young researchers. NTU 2025, the university's own five-year plan for research strategy, designates strategic research clusters in science, technology, engineering, mathematics (STEM) and the humanities, including the Future of Industry; Health & Society; Resilient Urbanisation & Natural Ecosystems; Artificial & Augmented Intelligence; Culture, Organisations & Society; and Brain & Learning.⁹ To support research promotion, NTU also secures research funding from both the government and industry.

Vice President White noted that NTU has been hiring young, highly specialized researchers as associate professors for the past 10 years in response to the predictions that artificial intelligence (AI) and computer science will become increasingly important in the near future. As a result, he says, NTU has been able to maintain the necessary personnel in these fields, which has led to an increase in citations of papers published by the university's laboratories and an improvement in the university's ranking index.

Vice President White also stated that NTU sometimes hires experienced world-class researchers to explore new fields. For example, in paleoseismology there was a research and development foundation in Malaysia, but that no such research and development foundation existed in Singapore. Therefore, in order to establish a new research institute, Professor Kerry Edward Sieh of the California Institute of Technology was appointed as a special professor in July 2008, and he is said to have been instrumental in launching NTU's paleoseismology program.¹⁰

In this way, both universities decide on science and technology fields to strategically prioritize, and are moving forward with the appointment of human resources and organizational development that are in line with these fields.

⁷ Refer to the NUS website. <https://nus.edu.sg/research/key-areas>

⁸ For more detailed trends, refer to Chapter 6 of the report "Policy and R&D trends of quantum technology in the leading countries of the Asia and Pacific regions" (March 2023) by APRC.

⁹ NTU at a glance 2023, p.19.

¹⁰ California Institute of Technology interview article. <https://heritageproject.caltech.edu/interviews-updates/kerry-sieh>
NTU also granted him with the title of Professor Emeritus in January 2020. <https://blogs.ntu.edu.sg/science/2020/09/16/ntu-honours-former-eos-director-kerry-sieh-with-emeritus-professorship/>

2.3.4 Promoting International Collaboration by Acquiring Outstanding Foreign Human Resources and Domestic Collaboration by Nurturing Domestic Human Resources

In Singapore, where natural resources are scarce, human resources are a precious resource. Talent Report 2022 points out that Singapore has been actively inviting outstanding foreign researchers, and that in 2020 foreign researchers accounted for 30% of all researchers in Singapore. This is because it would have been difficult for Singapore to rapidly raise its research and development capabilities to the level that they are at today without inviting top talent from abroad. On the other hand, both universities and the NRF expressed in this report their intention to strongly promote the development of domestic human resources in addition to inviting outstanding foreign researchers. This is because it is essential to nurture and promote domestic human resources in order to maintain stable, autonomous, and sustainable research and development capabilities over the long term and to put research and development results into practical use. The measures described in 2.3.1 were definitely taken against this background, including the upper limit on the proportion of international undergraduate students and no upper limit for international graduate students.

The specific responses of the government and both universities are shown below.

NRF CEO Beh stated that “We want talented people to see the world, so it's important to give them flexibility. If all talented Singaporeans stayed in Singapore, then a mutual network of researchers would not develop,” and mentioned that the active participation and success of domestic human resources will lead to the development of Singapore. For this reason, the government is working to improve the ecosystem for promoting science, technology, and innovation by appointing people with science and technology expertise not only as researchers, but also in policy formation and research support.

NUS Deputy President Thean also suggested a deeper involvement in international research networks. “The Research & Technology section is exploring the creation of new programs that will strengthen international cooperation. This is because our strength lies in our ability to conduct joint research with various universities around the world and the strong ties between individual professors. Similarly, we university executives typically do not intervene in what professors do or with whom they collaborate. We just provide support.”

On the other hand, depending on the characteristics of the academic fields, NUS will also emphasize nurturing domestic human resources. For example, when strengthening fields rooted in regional uniqueness, nurturing domestic human resources is valued. This attitude is also supported by CEO Beh’s statement that “...We are looking for top human resources from around the world and welcome anyone who is attracted to Singapore, but, at the same time, we also want to appoint local human resources... For example, when looking at research fields related to regional history from an anthropological perspective, it is important to secure domestic experts. This is because they live in this area and have better connections.”

Cui Xiao Wen, who oversees human resources policy at the NRF, emphasized the importance of finding a balance between foreign and domestic human resources, “Singapore is already in the midst of a declining population and is unable to maintain enough researchers on its own, so we are focused on continuing to welcome talented people from all over the world. However, at the same time, compared to our domestic human resource population, these researchers are more likely to migrate to other countries. Therefore, for overall stability, it is also important to

nurture Singaporeans.”

As for nurturing and maintaining human resources and cooperation in research development, interviewees were asked whether Singapore had taken any special measures from the perspective of economic security, but, compared to the United States and Australia, there did not appear to be any specific measures that need consideration. However, in some cutting-edge areas of science and technology international collaboration with public institutions is regarded as more difficult than with private institutions, such as quantum science and technology.



Figure 2-2: CREATE Campus (left) where the NRF is located, and the National University of Singapore university building (right)

Source: Photographed by the authors

2.3.5 Strengthening Industry-Academia Collaboration Both On and Off Campus

Singapore has a well-established startup ecosystem that encourages industry-academia collaboration. In particular, since the establishment of the Agency for Science, Technology and Research (A*STAR) in 2002, there has been strong exit-oriented R&D and close industry-academia-government collaboration. This can be seen in the following initiatives and facilities established by each research institute.

The CREATE Programme¹¹ is one of the bases for NRF to promote international collaboration and industry-academia partnerships. NRF has attracted leading universities from around the world, including the Massachusetts Institute of Technology and the Technical University of Munich, to collaborate with NUS and NTU. The campus is also home to more than 100 corporate¹² researchers and government officials, who conduct joint research and other activities in close proximity to each other, thereby creating a system that facilitates collaboration.

¹¹ Abbreviation for “Campus for Research Excellence and Technological Enterprise” CREATE’s activity base is located in University Town at NUS. Through the program, foreign universities receive funds from NRF and then develop joint research programs with NUS or NTU. <https://www.create.edu.sg/>

¹² As for the number of companies and their breakdown, both NUS and NTU explained that the companies “cover almost all major domestic and international companies.”

According to a researcher who is also involved in joint research with companies at A*STAR, Singapore has rich support systems for commercialization and industry-academia collaboration. “Many research institutes attached to government ministries and agencies are conscious of the issue of how to create valuable intellectual property and how to connect the results to startups. One of the main objectives is to activate industry-academia collaboration as a catalyst for this.”

In recent years, further changes have been seen in the direction of industry-academia collaboration. According to the A*STAR researcher, “Previously, the direction was to revitalize the economy by attracting large companies and multinational companies to Singapore, but nowadays the emphasis is being placed on how startups can create world-class industries by using technologies developed in Singapore.”

2.3.6 Other Related Matters: Nurturing and Maintaining Female Researchers

The previous sections showed measures that the Singaporean government and universities have taken to help NUS and NTU develop into world-class universities. One of the factors for maintaining human resources is that Singapore has a “high proportion of female researchers,” as is shown in Talent Report 2022. However, Singapore’s “high proportion of female researchers” is not necessarily due to special science and technology policies or to measures taken by the Singaporean government and universities. During the interviews in Singapore, the common explanations that were given were that “there is no quota system (ratio quota) to maintain a large number of female researchers” and that “the ratio of foreign nationals and women reached a certain level because outstanding human resources were promoted based on their achievements and abilities.” The common explanation given for after the recruitment phase is that “Singapore has a good environment, with childbirth support and childcare, so that female researchers can smoothly carry out their research.” In other words, as indicated in the Talent Report 2022, the “high ratio of female researchers” is not due to the contribution of science and technology policies, but rather to the social environment that encourages women’s advancement in society and family education.

On the other hand, the need to nurture and maintain even more female researchers was pointed out, and efforts to do so were observed at research sites. For example, when looking at the gender ratio by science and technology field, there is a tendency of more women in the biomedical sciences and fewer in the mathematical and physical sciences, which is not significantly different from other countries. In order to resolve the differences between fields, the need for further efforts to expand the number of female researchers in fields where the number of female researchers is low was emphasized by people at research sites.

3 Background and Aims for Formulating a National Strategy to Improve Scientific Research Capabilities

Singapore's science and technology promotion activities are driven by the five-year National Technology Plan, which began in 1990. Interim evaluations provide an opportunity to review the progress and effectiveness of investments, and in light of the rapid pace of change in science and technology, trajectories for the next five-year period are adjusted to serve as a driving force for further development. The various measures described below show that the NRF, which serves as the secretariat for formulating the five-year plan, works together with NUS and NTU to formulate a direction for the plan.¹³

These measures “encourage as many Singaporeans as possible to pursue science and technology as an education and as a career,” and, because Singapore is a small country with a limited working population, in many cases research and development budgets are distributed fairly to foreign researchers, not just to Singaporean researchers, as long as they are affiliated with a domestic research institute. This characteristic is clearly expressed in CEO Beh's statement that, “We complement policies that are friendly to Singapore with policies that are friendly to the global situation.”

Based on the results of interviews, the following will discuss the background and aims of how these concepts are reflected in the various systems described in the research report, and how they are manifesting themselves in improving Singapore's scientific research capabilities.

3.1 The Functions and Roles of Funding in Nurturing and Maintaining Research Human Resources

According to the NRF, much of the budget contributed through the five-year plans and other initiatives is aimed at strengthening basic and foundational research capabilities, and is allocated to universities and A*STAR research institutes from the Ministry of Education's budget as the “Academic Research Fund” (corresponds to Figure 3-1, “Core capabilities in universities and A*STAR research institutes”). In addition, with the aim of strengthening human resource development to promote science, technology, and innovation, a substantial budget is also allocated to “Talent Development.” In particular, various fellowships with abundant research funds are provided to enable scientific and technological personnel to start research in their first year. The NRF Fellowship (Talent Report 2022, section 3.2.1) is a typical example, which provides 2.5 to 3 million SGD over five years; and associate professor Yvonne Gao is one of the fellows.

A*STAR also uses academic research funds to support its affiliated research institutes and companies to

¹³ The Research, Innovation and Enterprise Council (RIEC), which formulated RIE2025, is chaired by the Prime Minister and includes the presidents of NUS and NTU from academia as committee members. <https://www.nrf.gov.sg/about/governance/riec/>

accumulate a pool of outstanding researchers and to attract talent.

Furthermore, while global companies have established bases in Singapore, many domestic companies are small- and medium-sized, with low research and development capabilities and difficulty in raising research and development funds on their own. As such, efforts are being made to promote research and development in these companies and to strengthen their scientific and technological capabilities, primarily through the use of public research funds.

The success of funding allocated to science and technology players can be seen in the steady increase in the share of Singaporean academic papers among the world’s most cited academic papers. Looking at the Field Weighted Citation Index,¹⁴ in 2000 Singapore was at 0.71, approx. 30% below the world average, but as of 2020 Singapore was at 1.58, more than 50% above the world average, which confirms the high level of success that the NRF’s promotion measures have had.¹⁵

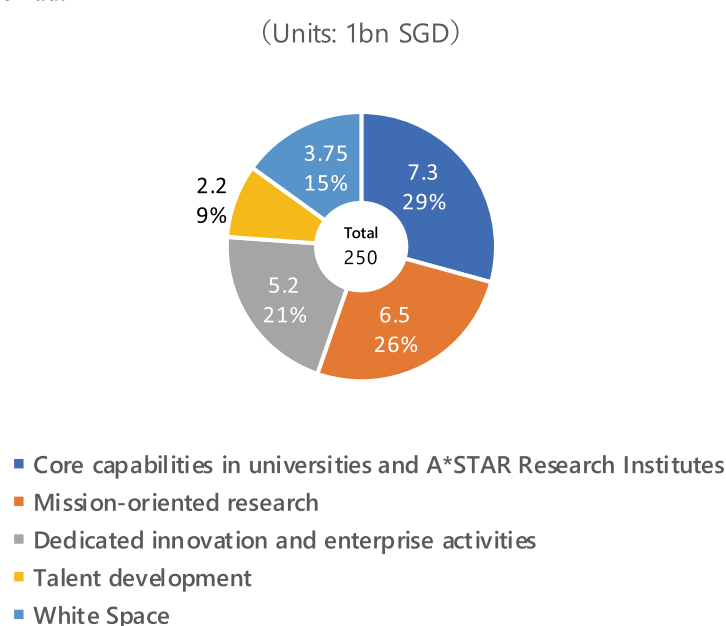


Figure 3-1: RIE2025 budget allocation
 Source: “Research, Innovation and Enterprise 2025 Plan” (p. 12 of the original document)

3.2 Policy Coordination with Related Domestic Organizations

A*STAR establishes research institutes under its umbrella, sometimes jointly with related organizations, in line with the national five-year plan and other science and technology policies, and universities also take coordinated responses based on national policies. NTU Vice President White, who also worked at A*STAR around the 2000s, explained this situation by using the pharmaceutical manufacturing industry as an example. At the time, the Singapore Economic Development Board (EDB) provided incentives to attract foreign direct investment (FDI), the NRF and A*STAR at the time established research institutes to support pharmaceutical companies, and

¹⁴ Field Weighted Citation Index is an indicator that measures a paper’s degree of citation compared to similar papers (same field, year of publication, and document type). By smoothing out differences, it can better measure citations. See also: Elsevier, “Measuring an Articles Impact,” Last updated on February 2, 2023.

¹⁵ Refer also to mentions in RIE2025. Page 41 of the provisional translation of the “Research, Innovation and Enterprise 2025 Plan.”

NTU established new schools and faculties to teach pharmaceutical sciences so as to nurture human resources. After clarifying the economic demand and as a result of creating the conditions for industry by strategically establishing and attracting research and development institutions, human resources training institutions, and major pharmaceutical companies to Singapore, in approximately 10 years the pharmaceutical manufacturing industry rapidly increased its share of GDP from 0% to approximately 25%. In this way, clear goals, intensive input to achieve them, and their integration into the research and development phase make it possible to achieve large results.

3.3 Maintaining Overseas Human Resources and Nurturing Domestic Human Resources

The Returning Singaporean Scientists Scheme, which was launched by the NRF in 2013 based on RIE2015, began with the aim of not only sending outstanding domestic human resources to foreign countries, but also of securing them as domestic human resources. As can be seen from the example of Aaron Thean, who returned from the United States as a member of the first phase of the program and is now the Deputy President of Academic Affairs at NUS, many of the returning scientists have been appointed to important positions in the promotion of science and technology in Singapore.

As for the balance between the use of foreign and domestic human resources, as was mentioned in 2.3.4, it is considered important not only to bring back outstanding human resources who have studied abroad, but also for Singapore to be able to domestically nurture its own citizens through the country's higher education system. Excessive competition is not necessarily desirable from the perspective of providing fair educational opportunities, but, if it is possible to attract outstanding domestic human resources to universities through appropriate competition, then domestic education can be done together with securing human resources from overseas and can be said to be an important factor in maintaining Singapore's future development.

As symbolized by the rapid progress of NUS and NTU, Kyota Inoue, Second Secretary at the Embassy of Japan in Singapore, acknowledged that "Singapore's research and education have reached an extremely high level through the balanced development of domestic and international human resources and the implementation of painful university reforms" and made the observation that "Singapore will most likely continue to do so in the future."

3.4 Reliably Maintaining and Flexibly Utilizing Budgets

As mentioned above, Singapore's five-year plans, including RIE2025, stipulate the total budget for the five years, and the budget allocation is determined based on the items shown in Figure 3-1.

Because research and development and human resource development are typically planned over multiple years, ensuring predictability is critical for steady and systemic implementation. What should be appreciated about Singapore's five-year plans is the fact that the budgets are reliably set aside without being reduced each year. This makes it possible for research institutes and universities to implement medium- to long-term plans without fear of budget cuts.

Additionally, 15% of the total budget in the five-year plan is called "white space," which is set aside as a program

implementation budget for responding to new policy demands that arise during the plan period and for new research opportunities. This allows the scientific community as a whole to secure a total budget and promote research and development in a fixed manner, while also providing a mechanism to flexibly respond to new situations, and this system is actually being put to use.

3.5 Future Prospects

To date, Singapore has rapidly expanded its scientific research capabilities in applied research fields such as biomedicine and engineering, and has developed corresponding human resource development programs (such as with Ministry of Health fellowships and Doctor of Engineering programs). In recent years, Singapore has also focused on strengthening its advanced science and technology by inviting the world's top researchers in fields such as quantum science and nanotechnology. NRF CEO Beh expressed his vision for the future, saying, "The NRF intends to focus not only on applied and developmental research, but also on the promotion of basic research," and that "the NRF will steadily train researchers for this purpose."

Compared with the facts highlighted in 3.3, Singapore recognizes in its human resources policy the need to steadily nurture its domestic human resources rather than solely relying on top foreign human resources.

4 Perceptions on Nurturing and Maintaining Human Resources from the Perspective of Research Sites

Based on interviews with NTU professor Sato, NUS associate professor Eda, and NUS associate professor Gao and a researcher of A*STAR, this section provides an overview of the perceptions on Singapore's development and maintenance of human resources from the perspective of research sites.

■ Experience from the Perspective of Funding Recipients

Many researchers voiced the opinion that “The existence of a comprehensive start-up support system made it possible for me to smoothly set up a research laboratory after transferring to Singapore.”

The authors also heard from current faculty members about their feelings on both the good and bad aspects of the harsh tenure-track system. Professor Hirotaka Sato at NTU said that, while he was studying in the United States as a postdoctoral researcher, his research topic caught the attention of Singapore, and he was offered a job. He said, “Even after being hired as a researcher, there is a strong possibility that, even if you achieve a certain level of research results, you will be fired after a few years if you cannot continue to do so until you obtain tenure. This is probably because the university starts by recruiting many people, not only myself, who are from completely unconnected situations. The harsh competition brought about by the strictness puts a lot of pressure on the mind and body, which, in a sense, can be considered a disadvantage. On the other hand, I think that being able to run a laboratory with wide discretion at a young age and being able to autonomously conduct research activities is an advantage that Japan does not have.”

Goki Eda, who is currently conducting research at the NUS Centre for Advanced 2D Materials, earned a doctorate in physics in the United States and was working as a postdoctoral fellow, stated “I chose Singapore as my research base because I was attracted to an environment where I could conduct research alongside world-class scientists such as prof. Antonio H. Castro Neto.” In 2014 the Centre sought to further strengthen its capabilities by recruiting Konstantin Novoselov, who won the Nobel Prize in Physics for his research on graphene, as a special professor from the University of Manchester in the United Kingdom.¹⁶ Associate professor Eda said that a “human resources chain” is occurring in which top talent attracts talented, next-generation human resources, who then in turn invite other top human resources.

■ Experience of Researching Directly Under NRF's Policy Direction

As mentioned in 2.3.3, government research institutes such as A*STAR conduct research activities that are directly linked to national plans. Because this determines the selection of priority research themes and the allocation of funds, it is necessary to constantly monitor national trends. A researcher that the authors spoke to, who has been

¹⁶ Refer to the NUS press release. <https://news.nus.edu.sg/nobel-laureate-konstantin-novoselov-joins-nus/>

working at A*STAR and formulating his own research field while referring to the national plan, said “In research fields that are directly influenced by national policy, new research institutes tend to be established or research functions are strengthened relatively soon after a strategy is announced, and the time span is short.” In light of the budgetary planning and flexibility pointed out in 3.4, this testimony is considered to be in line with the reality in Singapore.

■ Opinions from the Perspective of a Foreigner (Japanese national living in Singapore)

Conducting research activities in a foreign country often involves difficulties in social life. However, researchers working in Singapore generally feel that “The meritocracy is so pervasive that if you have unique ideas and sufficient achievements, then you will be evaluated fairly and will be able to find a place for your research activities.” As mentioned in 3.1, it is necessary for researchers to survive in a highly competitive environment in order to obtain sufficient opportunities, but it is also clear that this is a perfect environment for science and technology human resources who are willing to put their abilities to the test and receive high evaluations.

■ Insights from a Woman’s Perspective

A researcher affiliated with A*STAR felt that “I think there are overwhelmingly situations in which it is easy for colleagues to take time off due to family matters, including children. In addition to taking maternity leave, staff typically take time off without hesitation whenever an unexpected thing happens, such as when their child suddenly becomes ill. As such, they can continue to work without being forced to give up on their career.”

On the other hand, associate professor Gao, who was involved in this report, pointed out the lack of role models. She stated that it is essential for individuals in an organization, regardless of gender, to work together to address the issue of career paths for female researchers.

Associate professor Gao, who majored in physics and quantum science in both the United Kingdom and the United States, returned to Singapore with an NRF Fellowship¹⁷ and began her research activities. Her doctoral thesis, “Multi-cavity Operations in Circuit Quantum Electrodynamics,”¹⁸ deals with a method to realize quantum computing, and she has a compact experimental facility at the NUS Centre for Quantum Technologies, with which she is affiliated. In parallel with these cutting-edge research activities, she is also developing social activities to convey the fun of science to elementary and secondary education students. She highlighted that, “The proportion of female researchers in mathematics and physics in Singapore is not lower than that in Japan, but it is lower than that in other fields such as the biomedical sciences and the humanities and social sciences, and there is a lack of role models in society. I think it is important to teach mathematics and physics in the educational curriculum for young people, but there are not many outreach activities that focus on elementary and secondary education students.”

Additionally, researchers enter their doctoral program and pursue a doctoral degree when in their late 20s, which, biologically, is the time when they begin to think about pregnancy and childbirth. Her colleagues and friends also often faced a choice between “going on with scientific research or giving birth and raising children,” forcing them to sacrifice one aspect of their life for the other.

¹⁷ The NRF Fellowship is a system that provides support for research activities in Singapore to young researchers (including foreign researchers) who have obtained a doctoral degree (refer to page 21 of Report RR-02).

¹⁸ Refer to the abstract of her dissertation at Yale University. <https://physics.yale.edu/people/yvonne-gao>

She continued, “When discussing career paths for female researchers, it is often women who take the initiative. Coupled with this situation, people tend to say that ‘women’s problems should be solved by women.’ However, in reality, major changes will not be possible unless men, who make up the majority of the science and technology labor market, participate together and help organize things. This is a difficult concept for them to buy into, but I think we should continue our efforts by taking a variety of approaches.”

■ Problems with Japanese Universities Compared to Singaporean Universities

In Singapore, the number of faculty members who graduated from Singaporean universities is low, and foreign nationals account for around half of the faculty members, which creates a situation in which diverse human resources engage in friendly competition. In contrast, according to professor Sato, major Japanese universities with science and technology departments typically have many faculty members who graduated from Japanese universities, and there are very few foreign faculty members. This is a negative factor in forming networks with overseas countries and conducting creative research, and it can be said that the situation results in a loss of diversity in human resources. To resolve this problem, it is necessary to respond based on the example of Singapore, but this is a personnel issue that concerns many active faculty members, and it is presumed that major conflicts will need to be overcome.

5 Conclusion

As a summary of this report, the report items and results are summarized below from the perspective of nurturing and maintaining human resources.

5.1 Strengthening Nurturing and Maintenance of Human Resources through University Reform

In Singapore, the government and universities came together in the late 1990s and set a clear goal to (1) “develop from teaching universities to world-class research universities,” and, in order to be able to carry out the independent reforms necessary to achieve the goals, the major universities that were being transitioned became autonomous universities. In line with the goal setting for (1), Singapore’s world-class research universities were formed through the following measures that were taken by the government and universities in cooperation with each other.

- (2) Implementing major university reforms in terms of appointment and evaluation methods for human resources in order to shift from being education-centered to being research-centered
- (3) Steady and significant increases in university research funds by the government
- (4) Strategic research initiatives by establishing key science and technology fields for the country and universities
- (5) Promoting international collaborations by acquiring outstanding foreign human resources and domestic collaborations by nurturing domestic human resources
- (6) Strengthening industry-academia collaboration, both on and off campus

Of the above items, (3) largely depends on environmental factors outside of academia. On the other hand, each item other than (3) was independently addressed by each university. In particular, the university reforms in (2) were accompanied by significant pain and conflicts as faculty members were replaced with a shift from education-oriented personnel evaluations to research-oriented personnel evaluations. By carrying out these initiatives, the universities were able to invite many outstanding researchers from around the world, and, in 2020, Singapore as a whole was able to achieve a foreign researcher ratio of 30%, a high proportion that is unparalleled in any other country. The favorable treatment and attractive research environment commensurate with high ability and performance are supported by the testimonies of foreign researchers (Japanese researchers). There is no doubt that the concentration of such international and talented researchers has strengthened the research capabilities of Singapore’s universities, leading to their top positions in the Asia-Pacific region in university rankings.

5.2 The Importance of Nurturing Domestic Human Resources

In interviews, both the government (NRF) and the universities (NUS and NTU) explained that they strongly recognize the importance of nurturing domestic human resources. Although there is a firm recognition that Singapore’s scientific and technological innovation and the rapid development of its universities would not have been possible without the contributions of foreign researchers, there is a common understanding that excessive

dependence on foreign researchers for domestic research and development is not good for Singapore to maintain stable, independent, and sustainable research and development capabilities over the long term, nor is it good for the practical application of research and development results.

Based on this idea, Singapore has implemented preferential treatment for the development of its own citizens by limiting the number of international undergraduate students to a certain percentage (15%).

On the other hand, graduate students, faculty members at universities and research institutes, and researchers are hired meritocratically, based on the idea of non-discrimination between Singaporean citizens and foreign nationals. Furthermore, even after an individual has been hired as a faculty member or researcher, researcher support from the government and universities is essentially based on the idea of non-discrimination between Singaporean citizens and foreign nationals.

In this way, academic opportunities up to the undergraduate level are preferentially given to Singaporean citizens in order to nurture domestic human resources, while recruitment of faculty members and researchers for graduate schools, universities, and research institutes, as well as subsequent research support for them, is based on each individual’s abilities. This seems to be an attempt to create a fair and competitive research environment while promoting a balanced approach to acquiring outstanding foreign human resources and nurturing domestic human resources.

5.3 Suggestions for Japan

Table 5-1: Comparison of world university ranking scores for research universities in Singapore and Japan

QS World University Rankings

| University Name | NUS | NTU | Tokyo University | Kyoto University | Tohoku University |
|------------------------|------|------|------------------|------------------|-------------------|
| Ranking | 8 | 26 | 39 | 46 | 113 |
| Overall | 92.7 | 84.5 | 84.3 | 76.3 | 58 |
| Academic reputation | 99.4 | 91 | 100 | 98.7 | 72.4 |
| Employers’ reputation | 88.6 | 67.1 | 99.8 | 99.1 | 84.2 |
| Faculty student ratio | 76.5 | 77.6 | 90.4 | 94.7 | 98.5 |
| Citations per faculty | 93.2 | 94.4 | 70 | 49.3 | 29.6 |
| Intl. faculty ratio | 100 | 100 | 10.3 | 14.9 | 14.2 |
| Intl. students ratio | 81.9 | 80.2 | 29.2 | 20.8 | 13.8 |
| Intl. research network | 76.3 | 66.1 | 70 | 57.3 | 27.6 |
| Employment outcomes | 100 | 68.4 | 99.8 | 53.2 | 17.2 |
| Sustainability *new | 88.1 | 78.2 | 99.7 | 88.4 | 74.8 |

THE World University Rankings (as of Table 3-1, continued)

| University Name | NUS | NTU | Tokyo University | Kyoto University | Tohoku University |
|-----------------------|------|------|------------------|------------------|-------------------|
| Ranking | 19 | 32 | 29 | 55 | 130 |
| Overall | 90 | 82.3 | 83.1 | 75 | 63.8 |
| Teaching | 78.8 | 66.2 | 93.9 | 85.4 | 67.8 |
| Research env. | 94 | 80.9 | 94.2 | 84.3 | 66.4 |
| Research quality | 95.4 | 94.5 | 67.8 | 60 | 53.8 |
| Industry | 100 | 99.7 | 100 | 100 | 99.9 |
| International outlook | 91.1 | 93.3 | 49.7 | 45.7 | 58.5 |

Created by the authors from the 2024 edition of QS and THE university rankings. QS' s "Sustainability" category was newly established from this year's rankings.

In Japan, the world rankings for major domestic universities have been seen considerable declines over the long term, despite yearly fluctuations in both QS and THE rankings. Table 5-1 compares three Japanese research universities (the University of Tokyo, Kyoto University, and Tohoku University) with NUS and NTU, and shows which items they received poor evaluations for in the QS and THE rankings for 2024. In the QS rankings, "Citations per Faculty" is slightly lower than the overall evaluation, while "International Faculty Ratio" and "International Students Ratio" are significantly lower. Similarly, in the THE rankings, "Research quality" and "International Outlook" are lower than the overall evaluations. Considering that internationally co-authored papers generally tend to have more citations, it is clear that the weak points for Japanese universities are matters related to internationalization, such as the international faculty ratio and the international students ratio. In particular, Japanese universities' international faculty ratio is considerably lower than that of other major universities.

Japanese universities have long set their own goals as appropriate for promoting internationalization, such as the international faculty ratio, international student ratio, and the establishment of undergraduate degree courses taught in English, and for many years the Japanese government has also established programs to support the internationalization of various universities and continues to provide such support, but it seems clear that Japanese universities are lagging behind in internationalization when compared to the world's major universities.

Of course, rising in the world university rankings is not the ultimate goal for universities; under the current system, Japan has produced many outstanding researchers, and, since the beginning of this century, Japan has achieved remarkable results and is second only to the United States in the number of Nobel Prize winners (in the natural sciences). However, since the beginning of this century, Japan's global ranking in the top 1% and top 10% of highly cited papers has significantly fallen, and it is said that Japan's number of Nobel Prize winners will also slowly decline in the future. As pointed out by the five researchers interviewed in this report, in order to overcome this situation, it is now more necessary than ever for Japanese universities to take measures to raise their internationalization indicators, such as increasing the proportion of foreign faculty members and faculty members who have obtained a degree abroad or who have gained research experience abroad. To this end, it is considered essential that Japanese universities take drastic measures that have never before been seen at domestic universities, such as "large-scale compulsory quotas for inviting foreign researchers." The case of Singapore, which, as mentioned above, boldly carried out painful university reforms and achieved positive results, will be a highly instructive example for Japanese universities to follow in taking such measures.

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Research on the Nurturing and Maintaining of STI talent in Singapore (Addendum): The Driving Forces behind the Progress at NUS and NTU

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