GIGAKU PANEL REPORT

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長岡技術科学大学
Nagaoka University of Technology

GIGAKU PANEL REPORT

Past, Present and Future of Engineering Education Reforms

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Chapter 1. Engineers and Engineering Schools: Early History

Emergence of engineers

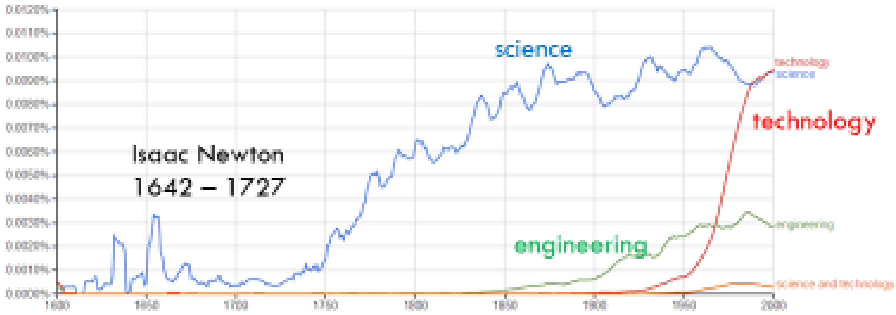
The English word "engineer" comes from a Latin word "ingeniātōrem", which means a person or an ability to devise new things[1]. As this etymology implies, ancestors of engineers in ancient world invented many items, but these were mainly military devices. For centuries in medieval times, people had been deprived of the freedom of creating new things and ideas: new things and ideas threatened the secular and religious power of ruling authorities.

That stifling situation changed gradually at the dawn of the modern era. Great works had been accomplished by scholars such as Nicolaus Copernicus (1473–1543), Johannes Kepler (1571–1630), Galileo Galilei (1564–1642), and Isaac Newton (1642–1727). Their ideas had completely changed the way mankind understands the universe. A historian coined the term *Science Revolution* to describe this change.

In the latter half of the eighteenth century, the Industrial Revolution began in Britain and then spread to continental Europe. A series of inventions and innovations drastically changed the mode of production, transportation, and daily life of people. These great changes created a new professional class: the engineers.

Figure 1 Occurrence of science, engineering, technology in English Books, 1600–2000

(chart drawn by Google books Ngram Viewer)



Source: Y. Mikami, Traditions of GIGAKU Education, the Second International GIGAKU Conference in Nagaoka (IGCN 2013)

[1] Oxford English Dictionary (OED) gives the following explanation.
Latin ingeniātōrem, noun and verb; 1. One who contrives, designs or invents; an author, designer; an inventor, a plotter, a layer of snares; 2. A constructor of military engines; 3. One whose profession is the design and construction of works of public utility, such as bridges, roads, canals, railways, harbors, drainage works, gas and water works, etc. From 18th century also civil engineer, for distinction from 2.

At the cusp of the medieval age and modern days, French philosopher Jean Jacques Rousseau (1712–1778) described this new profession in his monumental work "Social Contract" (1762). He likened the function of engineers to the functions of legislators of society. He wrote:

> The legislator is the engineer who invents the machine, the prince merely the mechanic who sets it up and makes it go.[2]
> (Social Contract, Book II, Chapter 7. The Legislator)

It is truly surprising that Rousseau, a founding father of modernity, noticed the emergence of this new profession at such an early stage. James Watt's invention of the steam engine was achieved only after his book appeared. The earliest engineering schools were born just a few decades before his book. The mining academy attached to Banská Štiavnica mine[3] was established in 1735. It is regarded as the first university-level institution of the engineering field. The French École des Ponts et Chaussées followed it, being established in 1747.

Rousseau intended to awaken readers to the fact that sovereignty of the society lay with legislators. In his proposed context, the legislators should be people, not kings. However, for our context, it is noteworthy that engineers are designers of society and that they are given this great mission and freedom to create new things. Furthermore, it happened only when civil liberty was implemented in the society. Additionally, it is noteworthy that this freedom is accompanied by responsibility to society. With due diligence as experts, engineers must consider all effects on society of their designed devices and services.

> Scientists investigate that which already is.
> Engineers create that which never has been.
> - Theodore Von Kármán (1881–1963)[4]

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[2] Social Contract & Discourses, Translated by G. D. H. Cole, New York: E. P. Dutton & Co., 1913. Cole translated French word "mécanicien" into "engineer". The Oxford English Dictionary picked up Rousseau's work under the headword "engineer."
Original French text: Celui-ci est le mécanicien qui invente la machine, celui-là n'est que l'ouvrier qui la monte et la fait marcher.
http://lavraiedemocratie.fr/IMG/pdf/jean-jacques_rousseau_du_contrat_social.pdf

[3] This academy is the precursor of Miskolc University and the Budapest University of Technology and Economics (BUTE) in Hungary. Miskolc University is one of the oldest international partners of NUT.

[4] Karman studied engineering at BUTE, Hungary.

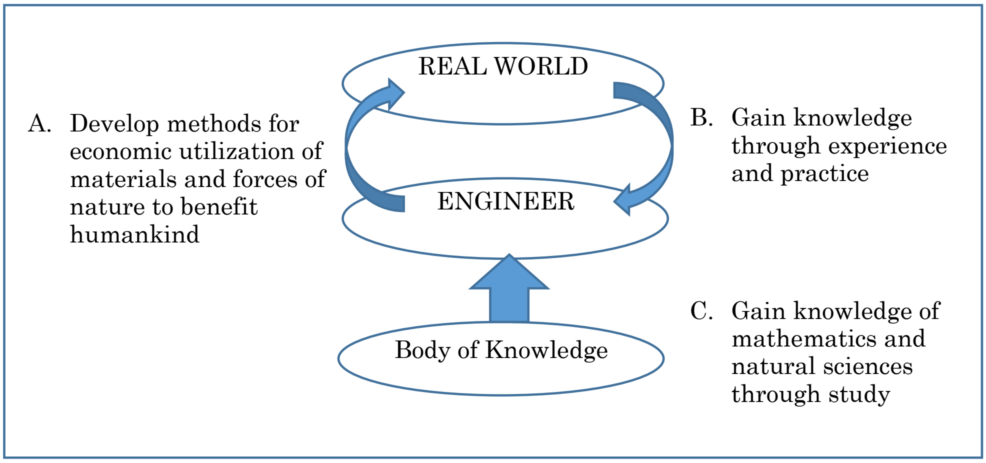
Functions of Engineers

Many definitions of engineering exist, but their underlying concepts are similar. Accreditation Board for Engineering and Technology (ABET) defines "engineering" as shown below.

> Engineering is the profession in which knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment to develop ways to use, economically, the materials and forces of nature for the benefit of [hu]mankind.

Figure 2 presents a schematic model of the functions of engineers. Process A is the main function of engineers. An engineer develops ways to use the materials and forces of nature for the benefit of humankind. The ABET definition adds the word "economically" to underscore the point that developed methods should be economically viable, not just theoretical or unjustifiable. Processes B and C show how engineers can develop the ways. There are two sources of knowledge. Through professional engagement/interaction with the real world, engineers learn a lot about the real world. What resources and forces are available for humankind? What products and services are required? What efforts are made by other engineers in the past and at present? Knowledge gained through this process is valuable for professional work. Engineers also learn a lot from the rich pool of knowledge accumulated in the past through studying. Although ABET lists only mathematics and natural sciences, knowledge of various other kinds can be involved in this process, such as economics, health science, behavior science, psychology, and various management techniques.

Figure 2 Schematic Model of the Functions of Engineers



The Birth of Engineering Schools

As described in the preceding section, the earliest endeavors to establish engineering education began in the mid-eighteenth century. In the following century, diverse approaches were taken in different parts of the world.

The German model, often designated as Humboldtian model, was implemented in the early nineteenth century at several state universities of Germany. It is still the model for research universities today. It emphasizes research work at a laboratory combined with academic teaching. The seminar teaching model was also established as a part of this model.

In Great Britain, Traditional Universities such as Oxford and Cambridge were not so eager for engineering subjects. Scotland had been the leader of engineering education. Engineering education at Glasgow University became highly distinguished under William John Macquorn Rankine (1820–72) and William Thomson (1824–1907, Lord Kelvin). By 1870 Kelvin and Rankine had made Glasgow the leading center of science and engineering education in Britain. However, in general, training of engineers was conducted based on apprenticeship. Practical onsite hands-on experience was assigned priority in this model.

Japan, as a latecomer to industrialialization, was keen to establish its own engineer educational system. When Henry Dyer (1848–1918), a Scottish engineer nominated by Professor Rankine, was sent to Japan and guided the establishment of the first engineering college in Japan, an interesting observation about engineering education in the contemporary world appeared in the esteemed journal, *Nature*[5]. According to this article, the approaches used by England, continental Europe, India and Japan can be summarized as shown below.

ENGLAND: ...[A] youth intending to become an engineer is taken from school at the age of sixteen being thereby deprived of the most valuable years of his education, and placed in some engineering manufactory, where he remains, perhaps until he is twenty.

CONTINENTAL EUROPE: The system goes to the other extreme, teaching the theory and discarding the practice. This system is as bad as the other.

INDIA: It can be [achieved] by a judicious combination of the two systems, allowing science and practical experience to work hand in hand together in the education. The Indian Government recognized this when it established the Royal Indian Engineering

[5] Engineering Education in Japan, Nature May 17, 1877. The article does not carry the author's full name. Only the initials (C.W.C.) are given.

College at Cooper's Hill for the systematic training of engineers for the Public Works Department of India.

JAPAN: Great work has been done by the Japanese Government in the establishment of an Imperial College of Engineering at Tokei [Tokyo], an institution which gives to its students a highly scientific training, combined with actual practical experience in engineering workshops.

Imperial College of Engineering: The First Engineering School in Japan

Dyer's design is summarized in his report to the Japanese Government in 1877, "The Calendar of Imperial College of Engineering"[6]:

"The course of training will extend over six years. The first two years will be spent wholly at College. During the next two years, six months of each year will be spent at College, and six months in the practice of that particular branch which the student might select. By this alteration of theory and practice the students will be able during each working half year to make practical application of the principles acquired in the previous half year. The last two years of the course will be spent wholly in practical work."

Based on this design, a six-year curriculum was developed. More than two hundred graduates were trained using this college in early Meiji Japan. The number of graduates was not large but those graduates played a leading role in the rapid industrialization process of Japan of the Meiji era. They constituted the first generation of engineers in Japan.

6 Imperial College of Engineering (KOBU-DAI-GAKKO) Tokei, CALENDAR, 1877.

Figure 3 Calendar of Imperial College of Engineering

	1st year	2nd year	3rd year	4th year	5th year	6th year
October through March	Lectures in classroom	Lectures in classroom	Lectures in classroom	Lectures in classroom	Practical on-site work experience	Practical on-site work experience
April through June	Lectures in classroom	Lectures in classroom	Practical on-site work experience	Practical on-site work experience		
July through September	No class Self-learning	No class Self-learning				

During six years of education, students had recurrently been sent to factories (mostly government-run factories), railway facilities, sea ports, telegram cabling sites, shipyards, and mines, where invited foreign supervisors were guiding construction and operation works. The total duration of on-site experience counted for almost half of their studying years; travel expenses were born by the college. Such continuous, multiple exposures to the real world formed an ideal learning environment for them to gain knowledge from experiences and practice.

Later in its history, this first engineering college was forced to merge with the College of Science when the Imperial University System was established in the late 1880s. When the merger plan was released, strong objections were voiced by the alumni. They sent a statement of objection to the Education Minister of Japan. The statement in 1888 was the following.

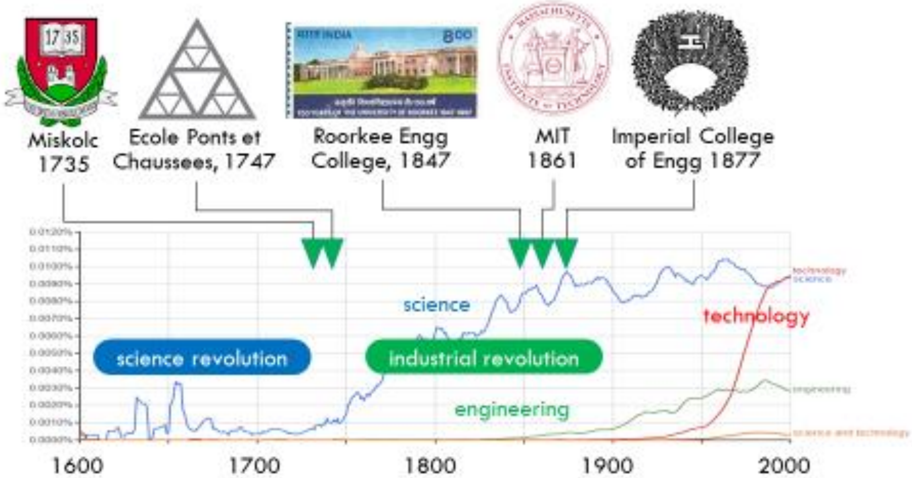
> In the first place the education policy of the Imperial College of Engineering is to nurture students armed with theory and practical knowledge of engineering to underpin business in the future while ripening their entrepreneurship to untiringly propel the development of industries without indulgence in mere academic argument. It is difficult to find a factory or laboratory all over Japan where our graduates are not found taking an active part in promising management positions. This fact proves our education policy is appropriate. Looking at the Department of Science of The University of Tokyo, on other hand, its major role is to find the truth faster than anybody else in the world so that industrial societies not only of Japan but also of Western countries earn an academic honor. The Department of Science might not be good in some degree at cultivating entrepreneurship, but it is considered natural because the department is a place for scientific research first and foremost. From the above argument it is obvious that the department and the college of engineering are two different institutes in their purposes and organizations except for their names

bearing "Universities." Therefore, abolishing the Engineering College and merging it with The University of Tokyo would be just as inadmissible at the reverse case.

In spite of the alumni's strong opposition, the Imperial College of Engineering was merged with the Department of Science of the Imperial University (later renamed The University of Tokyo). Several unique features of ICE were lost. The duration of education was shortened from six years to four years by streamlining multiple on-site experiences into one at the final year. Total duration of exposure to the real world was very much shortened.

As a result of this merger, ICE is often said to be a forerunner of the Engineering Department of the University of Tokyo, but actually ICE was partially lost or at least its unique features were weakened. Those lost or weakened features re-appear again in the post war engineering education reforms in Japan. This point is discussed later herein, in Chapter 2.

Figure 4 Engineering Education: Pioneers in Europe, Asia and the United States



Source: Y. Mikami, GIGAKU Education: Past, Present and Future, The sixth International GIGAKU Conference in Nagaoka (IGCN2017)

Chapter 2. Endeavors to Reform Engineering Education

This chapter presents a review of various reformation endeavors of engineering education since the end of World War II. Because of increasing demand for engineers and the advancement of technologies during that time period, great efforts have been made by various stakeholders in the world. Recently, recognition of mismatching between demand and supply of engineers, so-called "skills gap" issues, are major motives for reformation.

The first few sections of this Chapter are reports from panel member institutions. The remaining sections are brief summaries of other distinguished endeavors and frequently quoted reports related to this subject.

KŌSEN[7]-GIDAI[8] stream

The miraculously high growth of Japan in the 1960s was an important period for the Japanese education system, particularly for engineering education. In the 1960s, introduction of new technologies became a key element of industrial development. Economic growth was quite rapid. This circumstance necessitated timely and increased numbers of supplies of engineers. In Japan, many national universities expanded the size of their engineering departments and responded to growing demands for engineers. In the scope of this article, the most significant development was appearance of a new stream of engineering education. At five-year technical colleges, students enrolled at age of fifteen and receive a combination of classroom education with practical skills training at workshops. This system, called KŌSEN, has features that are wonderfully summarized in Blaine Harden's article "With workplace training, Japan's KŌSEN colleges bridge 'skills gap'," which appeared in the Washington Post on October 14, 2011.

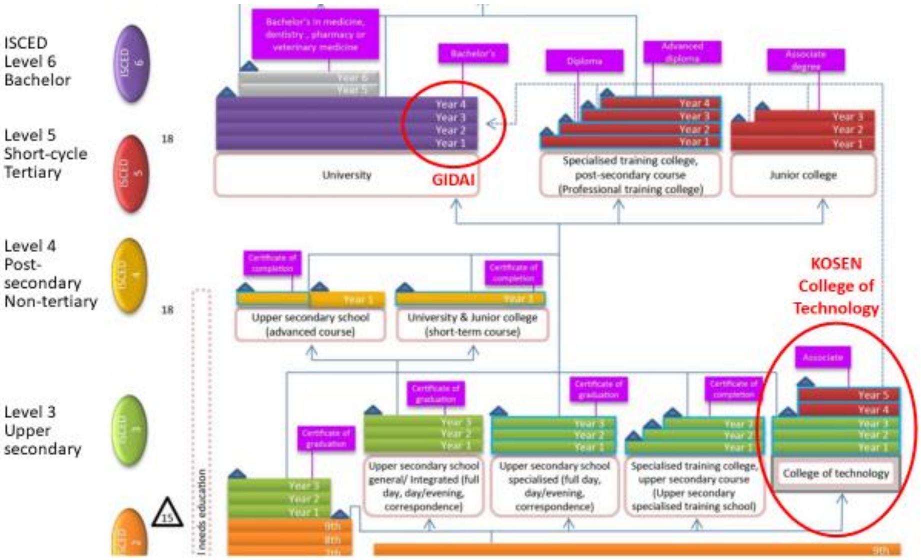
> Every year, about 1 percent of Japanese 15-year-olds turn away from high school. Then they turn into full-time nerds-in-training, enrolling in colleges where they make robots and write software, test diodes and study English, dirty their hands on factory floors and wait for job offers to come flooding in. Graduates of the standard five-year course at Japan's 57 national colleges of technology, collectively known as Kosen, can each expect about 20 job offers, school officials say. Students who stay on for two years

[7] KŌSEN is a shortened form of "KŌTŌ-SENMON-GAKKŌ". Its English translation was formerly College of Technology, but has since been changed to Institute of Technology.
[88] GIDAI is a shortened form of "GIJUTU-KAGAKU-DAIGAKU". GIJUTU means technology, KAGAKU means science, and DAIGAKU means university.

of advanced study receive about 30 offers. Kosen are hybrids of high schools and colleges that serve a small but important slice of the higher-education market, attracting students who combine an instinctive passion for building gadgets with above-average aptitudes in science and math. By fusing classroom rigor with workplace know-how, these colleges fix a failing of high schools and universities in Japan and in the United States. It is called the "skills gap": the bitter fruit of educational systems in both countries that aspire to make college accessible for all but which often produce students who, if they do get a degree, focus too narrowly on abstractions while neglecting the hands-on competence necessary for landing jobs.

A decade later, an additional reform was made to this educational stream by the creation of universities of technology in 1976. Two new universities were created in two industrial cities in Japan, Toyohashi and Nagaoka, which we collectively designate as using a shortened form of University of Technology in Japanese: GIDAI. Two sister universities are Toyohashi University of Technology (TUT) and Nagaoka University of Technology (NUT). In principle, original institutional designs of educational programs at TUT and NUT were the same. However, subsequent evolution has produced some slight differences between them.

Figure 5 KŌSEN and GIDAI (NUT) in UNESCO's ISCED Scale[9]

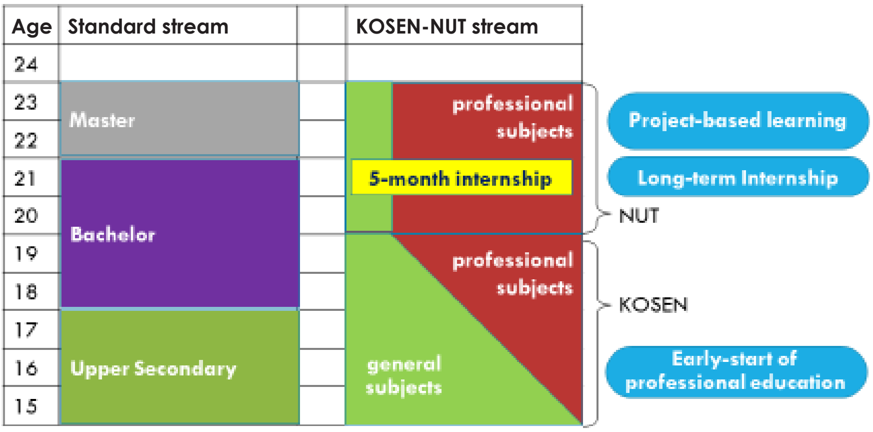


Source: OECD, Education Policy Outlook, JAPAN, November 2015.

Eighty percent of GIDAI students come from KŌSEN. They subsequently go through four additional years of engineering education at GIDAI; two years at the Bachelor level and two additional years at the Master level. At the end, the KŌSEN-GIDAI stream graduates have been trained for total nine years. Before GIDAI, KŌSEN graduates must spend additional years to continue study at universities. However, this inconvenience was removed by completion of the KŌSEN-GIDAI stream.

[9] ISCED: UNESCO's International Standard Classification of Education. Figure 5 is drawn based on the 2011 version of ISCED. Details and comparison with 1997 version are given in ANNEX II. KŌSEN are a combination of Level 3 and 5B in ISCED 1997, and a combination of Level 3 and 5 in ISCED 2011. Actually, KŌSEN's five year curriculum should be categorized as its own.

Figure 6 Standard Stream and KŌSEN-NUT Stream in Japan



The GIDAI system is unique in its institutional design when compared with then-existing engineering schools in postwar Japan. Its institutional design has four distinctive features.

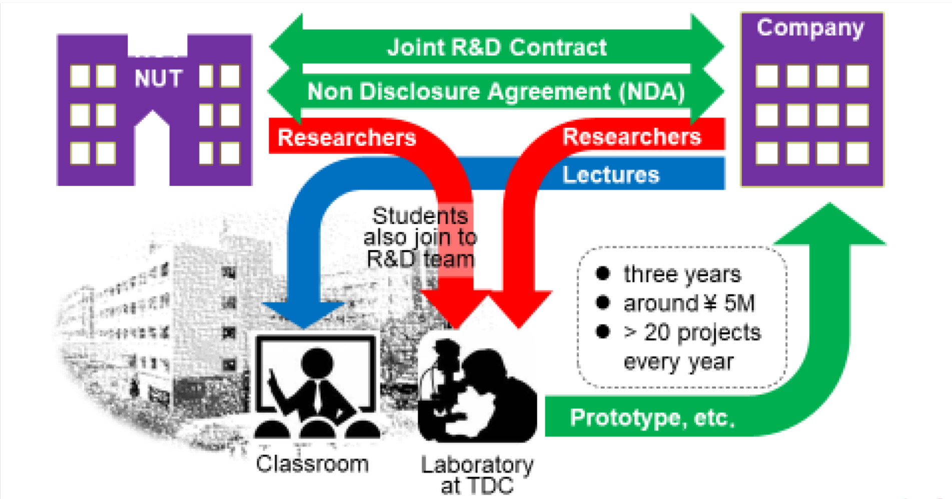
- **Faculty–Course Dual System**: Faculties are organized by members' research domain such as mechanical engineering and civil engineering. Furthermore, the academic course structure is almost identical to the faculty structure. However, in cases when cross-disciplinary teaching task is needed in an academic course, the relevant faculty will provide its resources to the academic course with highest flexibility. To assure this, Faculty and Course were declared as independent.

- **Faculty of Management Science**: To provide a sufficient content of managerial skills and knowledge to students, it was decided to have a new non-engineering faculty, called the Faculty of Planning and Management Science. Renowned researchers in the fields of humanities and social science fields were recruited. They provided common course lectures at both bachelor and master levels. Even in the master course, a total of six credits should be earned from management subjects.

- **Technology Development Center (TDC)**: The center was created to provide laboratory space and management scheme for joint industry–university collaborative projects. This center was the first of its kind in Japan. Until the late 1970s, public sentiments had been rather negative against industry–academia collaboration. Such was the case not only in Japan but also throughout the world.

Even in the US, the Bayh–Dole Act[10] was legislated in 1980, just one year before the TDC was established. Nominated graduate students joined joint development projects under non-disclosure agreement conditions. Joint projects constitute a small "Real World" located in campus. It serves as a training vehicle for students as well. The prime researcher of industry partner is usually appointed as a GIDAI professor, giving classroom lectures on related subjects.

Figure 7 GIDAI's Technology Development Center Scheme (NUT).



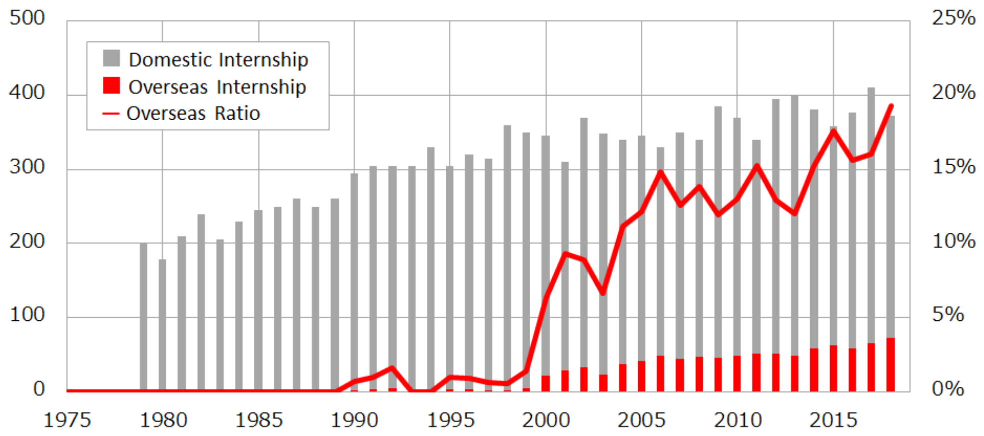
- **Mandatory long-term internship:** The half-year-long internship program was institutionalized as an essential component of the curriculum. With the support of Japanese business leaders (KEIDANREN), long-term internship arrangements were implemented for the entire student body of more than four hundred GIDAI students in 1979. It is truly a great advancement in engineering education in post-war Japan. However, one can say that it is a re-creation of the on-site work experience program of the Imperial College of Engineering in the early Meiji period. In that sense, the core of the educational program at ICE was reborn at NUT after

[10] The Bayh–Dole Act or Patent and Trademark Law Amendments Act are US legislation dealing with intellectual property arising from federal government-funded research. The key change made by Bayh–Dole was in ownership of inventions produced with federal funding. Before the Bayh–Dole Act, federal research funding contracts and grants obligated inventors (wherever they worked) to assign inventions they made while using federal funding to the federal government. Bayh–Dole permits a university, small business, or non-profit institution to elect to pursue ownership of an invention in preference to the government.

almost a century-long dormancy.

All students of NUT require internship experience for 4–6 months. This duration of the experience is necessary for students' full involvement in manufacturing and other processes of a company, not mere exposure to a new environment as visitors. This long-term internship also provides an opportunity for students to realize issues related to processes and associated topics, as well as abilities necessary to approach these issues. This opportunity gives students renewed interest and motivation for additional studies once they return to the school.

Figure 8 Number of Long-term Internship Students at NUT.



KOSEN in other countries: A Case of Mongolia

During the past few years, KOSEN systems have been implemented in several countries. Among them, Mongolia is the first country in which a Japanese KOSEN education system has been introduced. Already, three KOSENs have been established in the country.

New Mongol Colleges of technology offer five academic year courses. The goal is to foster skillful engineers who are willing to contribute their knowledge, theoretical, and practical experience with excellent communicative skills to the development of Mongolia. The college has employed over 50 highly trained and experienced teachers and engineers as well as enrolled 400 students who are chasing their dreams to build their nation themselves. Currently, the college is preparing for its first graduation ceremony, which will be held in June 2019.

The curriculum offers five years of special programs, eventually graduating students with a diploma degree in electrical and electronics engineering, civil engineering, chemical engineering, or mechanical engineering. Since 2014, six students have been granted full scholarship from the government of Japan, with 26 teachers participating in teacher's training course offered by JICA and National Institute of Technology, Japan, and 60 students who have been involved in the Sakura Science Exchange program and other programs. In addition, eight students have done internships in Japan. The college also co-operates closely with private companies, educational institutions, and governmental and non-governmental organizations to broaden their knowledge and share their experiences.

The college is receiving much positive feedback from the parents and co-operating companies related to this system.

In addition, similar overseas KOSEN projects have been launched in Mexico, Thailand, and Vietnam.

Fachhochschule

Fachhochshule[11] (University of Applied Sciences, UAS or Hochschule für angewandte Wissenschaften, HAW in German) were established as a result of the education reforms undertaken by the Federal Republic of Germany in the 1960s. The legislation (Fachhochschul-gesetze) which enables federal states to establish Fachhochschulen was passed between 1969 and 1972 in Germany. In Austria, similar decisions were made in 1990, and in Switzerland in 1995.

The Fachhochschule differs from the traditional university (Universität) mainly through its more practical orientation. The Fachhochschule represents a close relation between higher education and the employment system. Their practical orientation makes their graduates very attractive to employers. Subjects taught at Fachhochschulen include engineering, computer science, business and management, arts and design, communication studies, social service, and other professional fields.

Coursework generally comprises eight semesters (four years) of full-time study. In addition, **one or two practical training semesters are set to provide hands-on experience in real working environments**. The program concludes, usually after five years, with the final examination and a thesis (Diplomarbeit), which is usually an extensive project on a current practical or scientific aspect of the profession.

The traditional degree awarded at a Fachhochschule has been the Diplom (FH).

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[11] The German word "Fach" literally means "compartment" or "specialized subject (of study)". Construction of the German term "Fachhochshule" seems quite similar with that of Japanese term KŌSEN's in its original form KŌTŌ-SENMON-GAKKŌ. Here, KŌTŌ corresponds to HOCH, SENMON to FACH and GAKKŌ to SHULE.

Since 2000, conversion to international bachelor and masters degrees took place in Germany and Austria as part of the **Bologna Process**[12]. The degrees awarded by universities of applied sciences are formally equivalent to those of universities. The specification of the type of higher education after the academic degree, for example (FH) or (univ), has not been used since the Bologna Process. German Diplom degrees were mostly phased out by 2010.

In contrast to universities, colleges and universities of applied sciences have no authority to award a doctorate. Some German federal states, however, have pilot projects for doctoral studies at universities of applied sciences, in which certain subject areas at universities of applied sciences could, under certain conditions, be awarded a doctorate. Today, Fachhochschulen also conduct research. Research projects are either publicly funded or are sponsored by industry.

Universities of Applied Sciences in Switzerland

The Swiss higher education sector offers a complete and diverse range of study options at cantonal universities and federal institutes of technology, universities of applied sciences (UAS) and universities of teacher education (UTEs). Studies are based on the tiered Bachelor and Master structure. The cantonal universities and federal institutes of technology also award PhDs. All higher education institutions are required to pursue teaching and research and to offer continuing education and training courses and provide services to third parties.

The seven regional public universities of applied sciences were set up in the mid-1990s. The most commonly held qualification held by prospective UAS students is a vocational baccalaureate. UAS students develop the ability to apply scientific knowledge and methodologies. In some cases, they make use of their artistic abilities. Unlike tertiary level A universities, which mainly conduct fundamental research, UASs specifically examine applied research and development. At the crossroads between practical training and academic knowledge, UASs play an important role as drivers of innovation. Today, research activities account for around 25% of the total UAS operating costs.

Although not all UASs offer the full range of courses, the courses on offer

[12] The Bologna Process was a series of ministerial meetings and agreements among European countries to ensure comparability in standards and quality of higher-education qualifications. The process has created the European Higher Education Area under the Lisbon Recognition Convention. In fact, it is named after the University of Bologna, where the Bologna declaration was signed by education ministers from 29 European countries in 1999.

include engineering, information technology, architecture, construction and planning, chemistry, life sciences, agriculture and forestry, business and services, design, health, social work, music, theatre and other artistic disciplines. In addition, courses are offered in applied psychology, applied linguistics, and physical education.

The UASs primarily offer Bachelor degrees. They generally require three years of full-time study or four to five years of part-time study. Around 15% of those obtaining a Bachelor's degree go on to take a Master's, which generally takes about three semesters. Master's degree programs at UASs specifically examine research and engender a more advanced professional qualification. Because UASs are geared to the needs of the labor market, they also offer widely various continuing education and training courses, including advanced studies programs leading to the Certificate of Advanced Studies (CAS), Diploma of Advanced Studies (DAS) or Master of Advanced Studies (MAS).

Particularly, universities of applied sciences provide access to study at the tertiary level for professionals who have completed vocational education and training (VET) and who hold a Federal Vocational Baccalaureate. In 2016/2017, around 75,000 students were enrolled at a Swiss UAS, just fewer than 19% of whom came from abroad. Around 46% were women.

(This section was contributed by Prof. Kickmaier.)

Mondragon University

Mondragon University (Mondragon Unibertsitatea in Basque, MU) is a non-profit cooperative private university in the Basque Country, officially established in 1997. It is part of Mondragon Corporation, the world's largest cooperative. Its main campus is in Mondragón, Gipuzkoa. MU has a commitment to social transformation, as specified in its participatory model and in the mechanisms guaranteeing social accessibility.

The origin of MU is as a polytechnic school opened by Don José María Arizmendiarrieta[13] in 1943. The polytechnic school provided the springboard for students of different backgrounds to new jobs. Arizmendiarrieta was intent on creating a company catering to the positions required by the students graduating from the school. That took the name of Ulgor, later renamed to Fagor. The school and its graduates' community grew along with the industrial development of the Basque Country.

[13] Father José María Arizmendiarrieta Madariaga (1915–1976) was a Spanish Catholic priest and founder of the Mondragón cooperative movement in the Basque Autonomous Community.

Through the methodology of Problem Based Learning and the combination of work and study, MU's teaching model involves companies and institutions intensively in educational processes. Reduced classes for active learning methodologies foster personal objectives and expectations and facilitate work at cross-curricular competencies through multi-communication, problem solving, leadership, etc. Students can move easily from the classroom to the workplace because some companies of Mondragon group are located on the MU campus. Key points are developing the "teacher/mentor" function in the company, teaching this new teacher how to accompany the student, and providing feedback to students in the learning process are key points. At MU, the campus and real world are integrated not only logically; they are also physically integrated. In addition, teaching faculties are members of the Mondragon Cooperative. From time to time they work for group companies. Such liquidity of staff gives faculty pro-business mindset and business skills.

The motto "Learning from Reality" is implemented along with the following four directions.

- INNOVATIVE: A university that has constructed its own educational model that is exportable around the world
- APPLIED: A university linked to companies, to reality, where "learning by doing" is not a slogan. It is the DNA
- CLOSNESS: People mutually cooperate, co-create, and relate. They are educated in an atmosphere of trust. These are the main characteristics of MU
- PERSONALIY: A culture of entrepreneurial, hard-working people committed to a project for society

NUT signed an MoU with MU in 2015. Exchange of students started subsequently in 2016.

Indian Institute of Information Technology, Design, and Manufacturing

The Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram (IIITDM Kancheepuram, also IIITD&M Kancheepuram) is an Institute of National Importance established in 2007 by the Ministry of Human Resource Development, Government of India to pursue design and manufacturing oriented engineering education and research, and to promote the competitive advantage of Indian products in global markets.

The existing system of technical education in India, although huge and diverse, has specific emphasis on analytical capabilities. The need exists for skill sets that are appropriate for design and development and prototyping using modern tools and techniques. Product Lifecycle Management (PLM) approaches addressing the entire cycle from R&D, manufacturing, quality assurance, distribution, maintenance and disposal of new products is gaining currency. Therefore, a need was felt for setting up a specialized institution having a curriculum based on an inter-disciplinary approach and synthesis with emphasis on design and manufacturing, adopting information science based modern tools and techniques to adapt continuously to changing needs of the industry in the late 1990s. The government of India approved a proposal for the setting of two such institutes initially: one in Kancheepuram and another at Jabalpur with mentoring from IIT Madras and IIT Kanpur.

The two IIITDMs started functioning from mid-2000. They now offer Design Centric Engineering academic programs in broad areas of computer science, electrical and mechanical engineering at UG, PG, and PhD levels. Considering the need, the government of India subsequently established another IIITDM at Kurnool, totaling three institutes.

(This section was contributed by Prof. Gnanamoorthy)

NUT signed an MoU with IIITD&M in 2015. Exchange of students started subsequently in 2016.

Cooperative Education or Work-Integrated Learning Paradigm

The World Council and Assembly on Cooperative Education was founded in 1983 to foster Co-Operative Education and Work Integrated Learning programs worldwide. Its founders were college and university presidents, educational specialists and employers from Australia, Canada, Hong Kong, the Netherlands, the Philippines, the United States, and the United Kingdom.

At its inception, the World Council and Assembly on Cooperative Education identified three objectives:

- Build a membership of educators and employers from around the world
- Hold biennial world conferences on Co-operative Education
- Develop a newsletter devoted to issues involved in Work Integrated Learning and Co-operative Education.

The World Council and Assembly on Cooperative Education is the only organization devoted to Cooperative and Work-Integrated Education on a global basis. It is an aggressive advocate of programs combining professional work experience with classroom teaching. The World Council and Assembly on Cooperative Education was renamed The World Association for Cooperative Education (WACE) in 1991 and was merged with the National Commission for Cooperative Education (NCCE) in 2010.

Today, WACE has over 4,000 WIL Colleagues worldwide.

Nagaoka University of Technology has been sending representatives to WACE biennial world conferences since 2015. It joined as a member of WACE in 2018.

Problem-Based Learning and Work-Integrated Learning seems similar, especially when real-world problems are given to students in the former model. The Japanese GIDAI long-term internship program also throws students into the real world workplace.

IAESTE: Overseas Technical Experience

The International Association for the Exchange of Students for Technical Experience (IAESTE), an international organization founded in 1948, is exchanging students for technical work experience abroad. Students gain relevant technical training lasting from 4 weeks to 18 months.

IAESTE was founded in 1948 at Imperial College, London. The Imperial College Vacation Work Committee headed by Mr. James Newby initiated a meeting with national organizations from 10 European countries in a post war effort to promote better understanding among countries and cultures.

Since 1948, the association has grown to include more than 80 countries worldwide. It has exchanged more than 300,000 students. IAESTE exchanges around 7000 students annually, playing an important role in giving technical undergraduates practical work experience and a global perspective.

PBL Paradigm

During a last few decades, several new engineering education paradigms emerged. One early effort is Aalborg University's Problem-Based Learning model in engineering.

Aalborg University (AAU) is a Danish public university with campuses in Aalborg, Esbjerg, and Copenhagen founded in 1974. AAU differentiates itself from the older and more traditional Danish universities with its emphasis on interdisciplinary, inter-faculty studies, an experimental curriculum based on an interdisciplinary basic course with subsequent specialization, and its pedagogical structure based on problem-centered, real-life projects of educational and research relevance. The latter has become known and recognized internationally as The Aalborg Model.

With the problem-based, project-organized model, semesters at AAU are centered on complex real-life problems. Students working together in groups attempt to find answers to them in a scientific manner. In February 2007, the foundation of the

UNESCO's UICEE[14] Centre for Problem Based Learning (UCPBL) devoted some recognition to Aalborg University, which subsequently led to the appointment of AAU as UNESCO Chair in problem-based learning.

As this memo described earlier, the function of engineers is to interact with the real world and to try to solve problems there. The problem-centered approach of the Aalborg Model seems to give most appropriate preparations for engineering students.

Later in 1997, Olin College of Engineering was created as a private undergraduate engineering college in Needham, Massachusetts, USA. Olin College is notable for its small size and project-based curriculum. Much of Olin College's curriculum is built around hands-on engineering and design projects. This project-based teaching begins in a student's first year and culminates in two senior "capstone" projects. In the engineering capstone, student teams are hired by corporations, non-profit organizations, or entrepreneurial ventures for real-world engineering projects.

UNESCO Four Pillars for Learning (Delors Report)[15]

The Delors Report was a report created by the Delors Commission in 1996. It proposed an integrated vision of education based on two key concepts, **'learning throughout life'** and the **four pillars of learning, to know, to do, to be and to live together.** The four pillars of learning are fundamental principles for reshaping education. It is not particularly addressing engineering education. However, it gives a framework for the review and planning of educational reforms in general.

Table 1 UNESCO's Four Pillars for Learning

Learning to know	to provide the cognitive tools necessary to comprehend the world and its complexities better, and to provide an appropriate and adequate foundation for future learning
Learning to do	to provide the skills that would enable individuals to participate effectively in the global economy and society
Learning to be	to provide self-analytical and social skills to enable individuals to develop to their fullest potential psycho-socially, affectively as well as physically, for a well-rounded 'complete person
Learning to live together	to expose individuals to the values implicit within human rights, democratic principles, intercultural understanding and respect and peace at all levels of society and human relations to enable individuals and societies to live in peace and harmony

[14] International Centre for Engineering Education

[15] Report to UNESCO of the International Commission on Education for the Twenty-first Century (Delors Report)

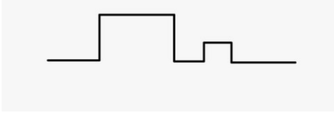
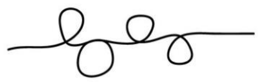
Stanford 2025

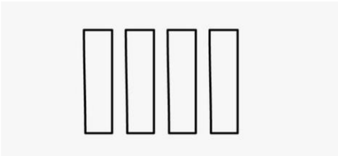
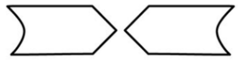
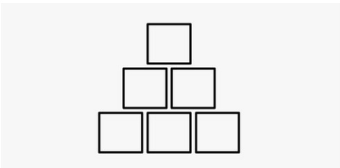
Stanford University announced a futuristic vision called "Stanford 2025" in 2014. Its scope is not limited to engineering, but the development work was funded by School of Engineering. Core members of the team are from its Design School (d.school). The vision gives us an exciting insight into the future of learning (scene in the year 2100) and into what changes the university might undergo in a coming century. The development process itself is futuristic too. The website can be explained as below.

> The @Stanford Project, which ultimately generated the Stanford2025 exhibit and website you're reading now, was sparked at the **d.school** in Spring 2013. Given the contemporary emphasis being placed on experimentation with online learning, we wondered what interesting changes were also starting to happen in the in-person, physical learning environment? To explore this question further, the project was **funded by Dean of the School of Engineering**, Jim Plummer.
>
> The project included three classes, a series of workshops, and the development of tools to support individuals who share the goal of experimenting towards a future Stanford, in addition to an experienced project team that worked currently to synthesize and build on the ideas and research initiated by the students and project partners. Design work continued both inside and outside of classes for a year, creating the foundation for the exhibit, which debuted in May 2014.

The key words used to describe the future of Stanford are Open Loop University, Paced Learning, Axis Flip, and Purpose Learning. These keywords are explained by the pairs of short phrases and hand-drawn pictorials presented below.

Figure 9 Stanford 2025.

Keyword	From (current situation)	To (in the year 2100)
Open Loop University	Students receive four years college of education, front-loaded at the beginning of adulthood. 	Students receive a lifetime of learning opportunities. 
Paced Learning	Structured 4-year courses of study advanced students by seat hours on a quarterly rhythm.	Three phases of varied lengths provided personalized, adaptive, calibrated learning

		
Axis Flip	Knowledge within a particular discipline was the criteria for graduation; skill development was secondary. 	Stanford flipped the axes so that skill development became the foundation. 
Purpose Learning	Students decided Majors and focus their studies around set requirements. 	Students declared Missions and coupled disciplinary pursuit with the purpose that fueled it. 

From the next section, interesting unique models of engineering education will be introduced. All of them are models from NUT international partners. A big shift of manufacturing centers is occurring throughout in the world. This shift is expected to be accompanied by a shift of engineering educational centers. Let us quickly review the cases of Basque Country and India.

Global Accreditation of Engineers

Let us start from the creation of the forerunner of ABET in North America. In 1932, the Engineers' Council for Professional Development (ECPD), an engineering professional body dedicated to the education, accreditation, regulation, and professional development of engineering professionals and students was created in the United States. This organization later became the Accreditation Board of Engineering and Technology (ABET).

Table 2 General Criteria of ABET

Criterion	Major point (first sentence)
1) Students	Student performance must be evaluated.
2) Program Educational Objectives	The program must have published program educational objectives that are consistent with missions of the institution, the needs of the program's various constituencies, and these criteria.
3) Student Outcomes	The program should have documented student outcomes that prepare graduates to attain the program educational objectives.
4) Continuous Improvement	The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained.
5) Curriculum	The curriculum must develop the following subject areas effectively in support of student outcomes and program educational objectives.
6) Faculty	Each faculty member teaching in the program must have expertise and educational background consistent with the contributions to the program expected from the faculty member.
7) Facilities	Classrooms, offices, laboratories, and associated equipment must be adequate to support attainment of the student outcomes and to provide an atmosphere conducive to learning.
8) Institutional Support	Institutional support and leadership must be adequate to ensure the program quality and continuity.

Source: ABET Engineering Technology Accreditation Commission, Criteria for Accrediting Engineering Technology Programs, as of October 20, 2017.

The Washington Accord is an international accreditation agreement for professional engineering academic degrees between the bodies responsible for accreditation in its signatory countries. Established in 1989, the full signatories as of 2017 are Australia, Canada, Taiwan, Pakistan, China, Hong Kong, India, Ireland, Japan, Korea, Malaysia, New Zealand, Russia, Singapore, South Africa, Sri Lanka, Turkey, the United Kingdom, the Philippines, and the United States.

The agreement recognizes substantial equivalence of programs accredited by those signatories. Graduates of accredited programs in any signatory country are recognized by the other signatory countries as having met the academic requirements for entry to the practice of engineering. Recognition of accredited programs is not retroactive. It takes effect only from the date of admission of the country to signatory status.

CDIO Initiative

The CDIO Initiative is an educational framework that emphasizes engineering fundamentals set in the context of conceiving, designing, implementing and operating real-world systems and products. The CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment. The CDIO approach uses active learning tools such as group projects and problem-based learning, to improve engineering students' technical knowledge as well as communication and professional skills. Additionally, the CDIO Initiative provides resources for instructors of member universities to improve their teaching abilities. CDIO is a trademarked acronym representing Conceive–Design– Implement–Operate.

Table 3 Comparison of CDIO Syllabus and ABET Accreditation Criteria

CDIO Syllabus 2.0 (2010)	Corresponding ABET Criterion
1. Context of engineering education	1) Students 2) Program Educational Objectives
2. Learning outcomes	3) Student Outcomes
3. Integrated curriculum	5) Curriculum
4. Introduction to engineering education	
5. Design–Implement practice	Not described explicitly
6. Engineering work places and laboratories	7) Facilities
7. Integrated learning experience	Partially described in 5)
8. Active learning	Not described explicitly
9. Enhancement of faculty competence	6) Faculties
10. Faculty teaching competence	
11. Learning assessment	1) Students
12. Program evaluation	4) Continuous Improvement

The CDIO concept was conceived originally at the Massachusetts Institute of Technology in the late 1990s. In 2000, MIT formally founded the CDIO Initiative in collaboration with three Swedish universities. The CDIO Syllabus was published in 2001; ver. 2.0 was issued in 2011.

Actually, CDIO is not an accreditation scheme. The assessment of compliance to CDIO Standards is a self-report process. An engineering program that must be evaluated based on CDIO gathers its own evidence and uses the rubrics to rate its status with respect to each of the 12 CDIO Standards. Table 3 presents a comparison of CDIO standards and ABET Accreditation criteria.

MIT Global Review Report of Engineering Undergraduate Education[16]

At the end of this section, MIT's most recent report is introduced to present a review of recent trends in engineering education around the globe.

This report, published in March 2018, represents results of comprehensive study of the global state-of-the art in engineering undergraduate education. This study was undertaken to inform Massachusetts Institute of Technology's New Engineering Education Transformation (NEET), an initiative charged with developing and delivering a world-leading program of undergraduate engineering education at the university. The study was structured in two phases, both of which used one-to-one interviews as the primary evidence gathering tool.

Phase 1 conducted between September and November 2016. Phase 1 provided a snapshot of the cutting edge of global engineering education and a horizon scan of how the state-of-the art is likely to develop in the future. The analysis drew on interviews with 50 global thought leaders in engineering education and identified the most highly regarded current and emerging university leaders in the field.

Phase 2, conducted between March and November 2017. Phase 2 involved case studies of four selected institutions identified during Phase 1 as being 'emerging leaders' in engineering education: Singapore University of Technology and Design (Singapore), University College London (UK), Charles Stuart University (Australia), and TU Delft (Netherlands).

Together, the two phases of the study are informed by interviews with 178 individuals with in-depth knowledge and experience of world-leading engineering programs. The report addresses five key questions.

1. **Which institutions are regarded as the 'current leaders' in engineering education?** Olin College of Engineering and MIT were both cited by most thought leaders consulted in Phase 1 as the 'current leaders' in engineering education. Other highly rated universities include Stanford University, Aalborg University, and TU Delft. Many interviewees noted that the engineering education sector is entering a period of rapid change. They therefore anticipated considerable movement in global leadership in the coming years.

2. **Which institutions are regarded as 'emerging leaders' in engineering**

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[16] http://news.mit.edu/2018/reimagining-and-rethinking-engineering-education-0327

education? A number of institutions were cited consistently by Phase 1 thought leaders as global 'emerging leaders' in engineering education. They include Singapore University of Technology and Design, Olin College of Engineering, University College London, the Pontifical Catholic University of Chile, and Iron Range Engineering

3. What features distinguish the 'current leaders' and 'emerging leaders' in engineering education? Institutions identified as 'current leaders' in engineering education tended to be well-established US and European research-led universities catering to large student cohorts. Good educational practices highlighted at these institutions included user-centered design, technology-driven entrepreneurship, active project-based learning and a specifically examine rigor in the engineering 'fundamentals'. The group of 'emerging leaders' represented a new generation of engineering programs, many of which were developed from a blank slate or which were the product of systemic educational reform, and which were often shaped by specific regional needs and constraints. Distinctive educational features of the 'emerging leaders' include work-based learning, multidisciplinary programs and a dual emphasis on engineering design and student self-reflection. Case study evaluations suggest that the 'emerging leader' programs have benefitted from strong and visionary academic leadership, a faculty culture of educational innovation and new tools that support educational exploration and student assessment.

4. What key challenges are likely to constrain the future progress of engineering education? A range of barriers that continue to constrain positive change in engineering education worldwide was identified. These include aligning government and higher education goals, **the challenge of delivering student-centered active learning to large student cohorts**, **the siloed monodisciplinary structure of many engineering schools**, and **faculty appointment and promotion systems that are not perceived as rewarding teaching achievement**.

5. What is the future direction for the engineering education sector? Drawing on evidence from both phases of work, a horizon-scanning approach was used to anticipate both the future trajectory of the engineering education sector and the profile of the leading engineering programs in the decades to come. It pointed to three defining trends.

The first anticipated trend is **a tilting of the global axis of engineering education leadership**. Evidence from the study pointed to a shift in the center of gravity of the world's leading engineering program from north to south and from high-income countries to the emerging economic 'powerhouses' in Asia and South America. Many among this new generation of world leaders will be propelled by strategic government investment in engineering education as an incubator for the technology-based entrepreneurial talent that will drive national economic growth.

The second anticipated trend is **a move towards socially relevant and outward-facing engineering curricula**. Such curricula emphasize student choice, multidisciplinary learning, and societal impact, combined with breadth of student experience outside the classroom, outside traditional engineering disciplines and across the world. Although many of these educational features appear within engineering programs at the 'current leader' institutions, they are often "bolt-on activities" and are isolated within the curriculum. As a result, much of the benefit of these experiences remains unexploited because they are unconnected with other curricular components. Moreover, students are not encouraged to reflect upon and apply what they have learned in other areas of the degree program. In contrast to the 'current leaders', many institutions identified as 'emerging leaders' in engineering education typically deliver distinctive, student-centered curricular experiences within an integrated and unified educational approach. In most cases, their curricula were designed from a blank slate or were the result of a recent systemic reform. Experiences such as work-based learning and societally relevant design projects are embedded into the programs in a way that provides a solid platform for student self-reflection and a pathway for students to both contextualize and apply the knowledge and skills they have gained elsewhere in the curriculum. However, many of these 'emerging leader' exemplars such as Olin College of Engineering and Iron Range Engineering cater to small cohort sizes. The key innovations that are likely to define the next chapter for engineering education are the mechanisms by which such features can be integrated across the curriculum at scale: delivered to large student cohorts under constrained budgets. As expressed in the words of one thought leader, "The next phase in the evolution of engineering education is for the remainder of us to figure out how we can offer this type of quality of education at scale."

The third anticipated trend for the sector is therefore **the emergence of a new generation of leaders in engineering education that delivers integrated student-centered curricula at scale**. The case studies considered in Phase 2 point to a number of institutions that have developed such a model, where this curricular coherence and integration is delivered through a connective spine of design projects. For example, the Singapore University of Technology and Design curriculum is delivered through multidisciplinary design projects which contextualize and integrate learning across courses and years of study. A second example is the UCL Engineering curriculum, which structures the first two years of study in five-week cycles, where students spend four weeks acquiring a range of knowledge and skills that they subsequently contextualize and apply in a one-week intensive design project. Interviewees also suggested that, in the longer term, some of the world's leading engineering programs would increasingly deliver student-centered learning to large student cohorts through **a blend of off-campus personalized online learning and on-campus hands-on experiential learning**: "This is the future of the field, where the student is put at the center and uses the resources to facilitate team projects and authentic experiences; then put the taught curriculum online." A number of institutions are already moving forward with such an educational model.

Table 4 Events in Engineering Education Reforms after World War II

Year	Event
1886	University Deusto established
1945	University of Guanajuato established
1946	UNESCO established
1948	International Association for the Student Exchange for Technical Experience (IAESTE) formed
1956	Hanoi University of Science and Technology established
1959	Indian Institute of Technology Madras established
1961	KŌSEN system established in Japan
1969-1972	Fachhochshule (University of Applied Sciences, UAS) established in Germany Mongolian University of Science and Technology established
1974	Aalborg University, Denmark
1976	University of Technology (GIDAI) established at two industrial towns in Japan (Nagaoka and Toyohashi) based on GIGAKU paradigm
1980	The Bayh–Dole Act legislated in US
1983	The World Council and Assembly on Cooperative Education founded to foster Co-operative Education and other Work Integrated Learning programs worldwide
1989	Washington Accord signed
1992	UNITWIN/UNESCO Chairs Programme launched
1995	WTO formulated. Technical barriers, including cross-border accreditation of professionals became an important trade issue.
1996	UNESCO, Delors Report (Four Pillars of Learning) Boeing report
1997	Olin College of Engineering established Mondragon University officially established
1999	Bologna Declaration signed by 29 European countries
2000	CDIO Initiative launched (Conceive Design Implement Operate)
2001	CDIO Syllabus Version 1.0
2003	University of Antwerp established
2005	The First CDIO Conference
2007	Indian Institute of Information Technology, Design and Manufacturing established Zurich University of Applied Sciences established
2011	CDIO Syllabus Version 2.0
2014	New Mongol College of Technology established
2018 Mar	MIT's Global Review Report on Engineering Education
2018 May	Appointment of NUT's GIGAKU SDG Institute as UNESCO Chair on Engineering Education for Sustainable Development.

Chapter 3. Concept of GIGAKU

The preceding chapter presents a review of reformation endeavors of engineering education in various part of the world. Many interesting practices, new concepts, new paradigms are being introduced. In this chapter, the concept of GIGAKU will be presented first. Then its etymology is introduced. Additionally, we try to re-interpret the value of GIGAKU in relation with those new concepts and new paradigms.

What is GIGAKU?

The term GIGAKU was originally coined by Dr. Masamitsu Kawakami, the founding President of NUT, when the university was established in 1976. With this GIGAKU concept as the foundation, NUT has been building its unique educational programs by training students from KŌSEN colleges. NUT's educational programs have been successful as indicated by nearly 100% graduate job security and continuous high praise from industry[17].

On April 18, 1977, NUT held its first convocation ceremony. The founding president, Dr. Masamitsu Kawakami, made the following comments in his inaugural address to welcome the first group of entering students.

> A university has an obligation to make good use of research outcomes for society. If a university falls behind the rapid progress of society, then I would have to call that laziness of the university. University faculties should fully enjoy engagement in world renowned research and the creation of new fields and disciplines. The knowledge and vision of university staff will inspire students by touching the souls of young ones. This is the important process by which the university fosters creative minds.
> If someone asks 'why do I have to study?,' my answer would be for you to gain the ability to create things, to have a creative mind. There is no doubt that, foreseeing the future, Japan will need creative young people. One will not have to pay too much attention to scores, but each should develop one's own self-determining spirit and fully gain the ability to create things. Study hard; then leave for the real world. For this purpose, we university faculty members are here to work together with you.

[17] According to a Nikkei Shimbun (Japan Economic Journal) report dated June 8, 2016, NUT graduates are ranked No. 1 by personnel affairs staff of 3,600 listed companies in Japan. Especially, proactive attitudes, communication capabilities, and creativity of the graduates are the main points of appreciation.

M. Kawakami often quoted the following word of poet William Butler Yeats (1865–1939).

Education is not the filling of a pail, but the lighting of a fire.

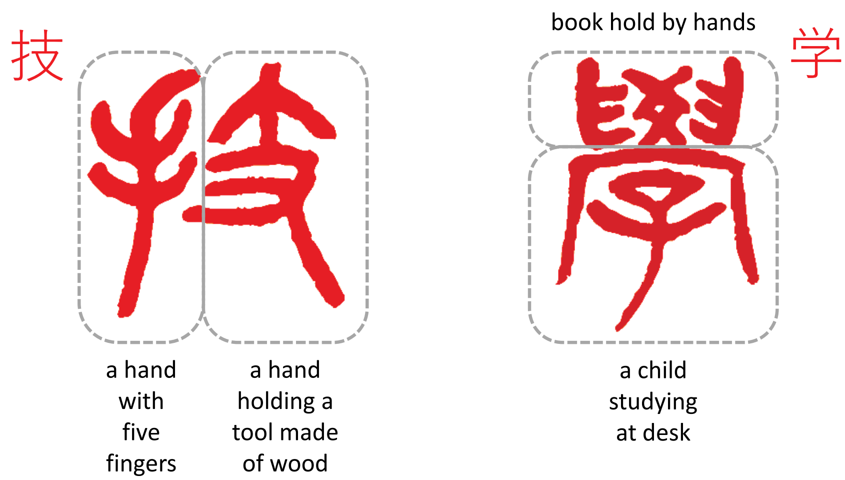
He even criticized that Japanese language has translated the word "education" wrongly as "KYOUIKU"[18]. The Japanese word carries a nuance of teaching, or "the filling of a pail." The essence of the process of education, as he said, is best summarized in Yeats' simple phrase. "Active-Learning", "Purpose-Learning" and other versions of the current day education reformers' motto are apparently alternative versions of the Yeats idea of education. GIGAKU education stands on the same education philosophy.

Etymology of GIGAKU

For non-Japanese speaking readers, it will be helpful to give some more explanation of the etymology of the term GIGAKU here. GIGAKU is a term composed of two word-roots: GI and GAKU.

In Japanese, GI〔技〕literally means all kinds of arts, engineering and technical works. GAKU〔学〕stands for disciplines in general when used as a suffix (see Chart 6 below) such as SU-GAKU (mathematics), KA-GAKU (chemistry), I-GAKU (medicine), and KEIZAI-GAKU (economics). Therefore, in short, GI-GAKU stands for the discipline of engineers.

Figure 10 Pictorial Interpretation of GIGAKU.



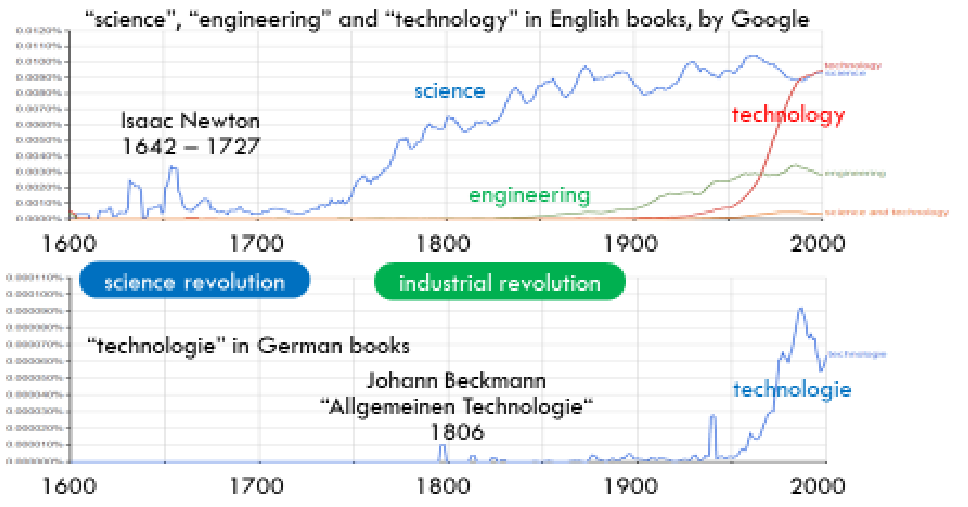
18 Kawakami suggested translation of this word to "KAICHI" [開智].

It is interesting to think about the term technology here. The English term "technology" comes from Greek word "τεκνη" (tekne)[19]. It means "art". The Oxford English Dictionary (OED) explains its meaning as "A discourse or treatise on an art or arts; the scientific study of the practical or industrial arts". As shown in Figure 1, occurrence of this word in English books abruptly increased only after the World War II. Earlier usage of this word is found in German books.

Johannes Beckmann (1739-1811) is regarded as a coiner of this German term "technologie". He wrote a book "Entwurf einer allgemeinen Technologie" (Draft on general technology) in 1806 and gave a scientific and systematic study of technologies for the first time. The suffix "-logy" is attached when the word means learning of something. He reviewed various industrial arts of craftsmen and sought generalized principles or laws among them.

One can find a sort of similarity between the construction of two words: "techno - logie" in German and "GI-GAKU" in Japanese. From this interpretation, both words are coined to mean

Figure 11 Occurrence of technology/technologie in English and German Books.
(Chart drawn by Google books Ngram Viewer)



Source: Y. Mikami, The First Panel on GIGAKU Education, October 2016.

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19 The Oxford English Dictionary (OED) gives the following explanation:
Greek τεκνολογια, τεκνη; 1. A discourse or treatise on an art or arts; the scientific study of the practical or industrial arts. 1615 Sir George Buck, A Discourse or Treatise of the third universitie of England. "An apt close of this general Technologie."

Core Value of GIGAKU Education

Through two rounds of discussion at the Panel on GIGAKU Education, participants exchanged views on what constitutes the ideal engineering education program, how it can be designed, etc.? During the discussions, as an organizer of the panel, NUT introduced the GIGAKU concept and practices. Participants introduced their concept and good practices. This document presented to the third round of the panel reviewed various good practices of reported cases around the world. Now is the time to summarize common features among all these good practices.

In the following part, common features are written under the title of credo. The objective of this panel discussion is not standard setting. A complete set of standards and criteria for engineering education is already available. It is not our intention to add new standards. The objective of this panel is rather to make a core value and a global alliance or partnership whose members share this core value, and who wish to stimulate each other for the sake of advancement and continuous improvement of engineering education. In such a context, the word "credo" seems to fit better to describe core values of the team. Following are the proposed set of credos.

Credo 1: Work-integrated learning

The importance and effectiveness of work-integrated learning has been described repeatedly in this document. The Imperial College of Engineering in early Meiji Japan adopted curricula of mixed class room teaching and workplace experience. NUT is inheriting this tradition, even extending it to a global scale. The Aalborg Model poses complex real-world problems to students. Mondragon University currently offers its students work-integrated learning opportunities on an on-campus basis. Its mottos are "Learning by Doing", "Learning from Reality", and "Cooperative Education", with the support of industrial partners. Industry–Academia coalition WACE is pushing work-integrated learning initiatives aggressively. The Loop-Learning proposed by Stanford also provides students a recurring combination of workplace learning and study at campus. The most recent MIT report on engineering education identified the trend of a move towards socially relevant and outward-facing engineering curricula. Exposure to the real world might be the most effective way to give students a learning opportunity, particularly at the "operating stage" of CDIO.

Arranging work-integrated learning opportunities is of course not an easy task for faculty. Faculty should find reliable industrial partners who offer such opportunities, should identify best suited supervisors on partner side who take care and guide students, and should arrange safe and affordable housing and transportation as well.

These are truly time consuming tasks for faculty and staff. In spite of all these difficulties and cost, doing so is worthwhile.

In addition to that, as the MIT report mentions (Chapter 2), one key challenge for reform practitioners is "how to deliver student-centered active learning to large student cohorts." On this point, the fact that GIGAKU education program at NUT is delivering long-term internship experience to the entire student body can be highly evaluated.

To gain practical experience in the real world workplace, education programs should ideally operate internship programs overseas. NUT is currently sending more than fifteen percent of undergraduate students to overseas destinations constantly. Furthermore, NUT is working together with international partner institutes to arrange in-bound internship opportunities for students of partner institutes. In several cases, NUT is becoming financially supportive for those students with cooperation from companies. This has occurred because it is beneficial for the receiving companies to have foreign students. Such bi-directional internships are expected to be the future of work-integrated learning programs.

Current university education tends to fail to address the needs of industry, particularly as represented by recruiters. Most faculty members have little or no industry experience and do not properly address real-world situations in the classrooms. That tendency might engender wider gaps separating the capabilities of the students and the needs of recruiters. The following means can be adopted to fill this gap.

1) Inclusion of industry experts as faculty/adjunct/joint faculty
2) Retired or senior industry experts might be invited periodically to academia or be permitted to interact using AV tools.
3) Permitting academic faculty to serve or spend a few weeks or months in industry
4) Permitting mini/small industries close to the university for efficient regular student visits and faculty interaction

Credo 2: Early start and recurring learning opportunity

Engineering education is more effective for younger students starting from as early an age as possible after compulsory education. As shown in Figure 6, Japanese KŌSEN education begins from the age of fifteen. Initially, the subject of study is mainly general subjects, but professional subjects gradually increase the portion. KŌSEN calls this "wedge-shaped curricula." Professional subjects include not only classroom lectures, but also practice at workshops, and short internship programs at actual workplaces.

The history of KŌSEN education and high appraisals to KŌSEN from foreign observers have proved that this concept is effective.

Exposure to engineering subjects at an early stage of learning seems to have several important benefits.

First, young people of the current day are placed under heated competition of university examination in many countries. Excessive competition based on scores, ranking of schools, etc. is depriving young people of chances to nurture natural curiosity and interest in making things, known as "Monodzukuri". Once such a chance is given, young people can develop their curiosity and interest. Consequently, the initial stage of engineering education should specifically examine nurturing of natural curiosity and providing of hands-on experience with machines, materials, and nature.

Exposure to real-world engineering problems at an early stage of learning has another advantage. Participants in work internship might realize their lack of knowledge to improve their effectiveness to perform a given task or solve problems for the task. These motivations acquired through real-world experience are the essence of purpose-based learning.

Here one point is noteworthy. In most countries, the age of fifteen is the dividing point of the vocational stream and standard stream. The direction of the student is given based on exam scores. Because of this common practice, an "early start" might give a misleading interpretation. The Japanese KŌSEN stream should not be classified as a vocational line. At KŌSEN, while providing rich hands-on training such as a vocational line, courses in high-level mathematics, electromagnetic theory, fluid dynamics, etc. are taught as well. Applicants to KŌSEN choose this line not because of the applicant score, but because of a *dream of becoming an engineer.* That is the uniqueness of KŌSEN.

In fact, NUT is currently collaborating with Mongolian and Mexican partners to build KŌSEN style education programs. The national umbrella institution of KŌSENs, National Institute of Technology (NIT), is collaborating with Thailand, Vietnam, and several other extra-national counterparts to establish KŌSEN programs overseas. Through these experiences, we have ascertained that the design or re-design pre-university level education presents difficult issues. Design of a national school ladder is a matter of national policy. We learned that well through our collaborative experience. Nevertheless, it can be attempted to include the KŌSEN concepts or professional courses during the early years of university education. It is also suggested that engineering universities should join together to organize joint competitions for engineering skills.

Another part of credo 2 is "recurring learning opportunity". Because the advancement of technology is so rapid today, no engineer can survive without refreshing knowledge and skills throughout their professional life. The UNESCO Delors Report assigns priority importance to "learning throughout life". The Stanford 2025 suggests "Open Loop University" and "Paced Learning". The General Accreditation Criteria of ABET, CDIO Standards also emphasize life-long learning. The GIGAKU also places high priority to recurring learning opportunities.

The GIGAKU education program at NUT has been providing a special learning opportunity for working engineers. This tailor-made program provides contents tailored to the needs of students. Because working engineers have difficulty in commuting to university campus, NUT is offering online, web-based learning contents on various basic engineering subjects, such as mechanics, electromagnetic theory, and electronic circuits. A platform provided by the Japan Massive Open Online Course [20] (JMOOC) is employed to deliver these courses. Many working engineers of Japanese industry are taking these courses today on a free-of-charge basis.

The NUT has been providing Continuing Professional Development Course (CPD Course) for international students with more than two years of working experience as engineers or researchers. The course started more than twenty years ago, with the support of the Association for Overseas Technical Scholarship (AOTS)[21]. Hundreds of thousands of overseas engineers have received training at AOTS since the 1960s. However, the training is, in principle, skill-based. The training duration is also limited, mostly to less than three months. Therefore, some of them wanted to develop their professional knowledge and skills further, and also wanted to get an academic qualification of Master level or more. To respond to such a demand, the CPD course was launched in 1995. Almost one-third of the graduate students studying at NUT are CPD Course students. The GIGAKU SDG Institute (for more details, see Chapter 4) renovated the CPD Course to the SDG Professional Course. The new course has become open to non-working students.

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[20] Currently 140 courses are provided, in which more than five hundred thousand people have studied at the JMOOC site. https://www.jmooc.jp/

[21] The AOTS was established in 1959 as a non-profit organization of Japan to provide technical training program for overseas engineers. Later training programs have been extended to include courses for management level staff. In 2012, AOTS has merged with another non-profit organization of Japan, the Japanese Overseas Development Corporation (JODC, established in 1970) and changed its name to the Overseas Human Resources and Industry Development Association (HIDA). Again in 2017, HIDA changed its name to AOTS, but the new AOTS acronym stands for "Association for Overseas Technical Cooperation and Sustainable Partnerships".

Credo 3: Sustainable Development Goals

Engineers are of a profession that directly affects the process of interaction between humankind and nature through the products and services they design and manufacture or provide. They should understand the possible effects of their products and services to the future conditions of the global society. More importantly, they have a capability to change the processes of interaction. Because of these reasons, engineering education institutes of the world should incorporate SDGs into their education programs. Based on this recognition, NUT proposed UNESCO to establish the GIGAKU SDG Institute.

To incorporate SDGs into engineering education, two points are apparently important. Good communication capability and the notion of fairness. Engineers in a coming age need to expand their communicating space, especially when confrongint some engineering matters in a global context, widening a person's communication network into global space is unavoidable. For expansion of the human network, engineers in a coming age must have a good command of multiple languages and have a power of understanding of diverse cultures. To do so, Mondragon University adopts a multilingual, actually trilingual (Basque, Spanish and English) educational model based on Problem Based Learning to acquire the knowledge.

At the basis of SDGs, a notion of fairness exists. In the coming age, we expect to face frequent occurrences of conflicts, conflicts attributable to population, to food, to energy, and to many other causes. Conflicts among generations are also an issue. To solve or, at least, to ease these conflicts, fairness is of crucial importance. Issues of human rights and global environment cannot be addressed properly without a notion of fairness.

Here, it is noteworthy that the objectives of the SDGs must be associated and taught hand-in-hand with professional subjects. Goals and targets of SDGs are defined at an abstract level, in principle. It is necessary to help students find a link between professional subjects and SDG goals and targets.

Credo 4: Evaluation by industry and society

Overall achievement of educational goals should be assessed in the long run, not be assessed term-by-term or subject-by-subject. The separation of evaluation from education is important. Evaluation is not a professor monopoly. Education is primarily given by professors for a specific field, but evaluation might be separately conducted by experienced engineers or other team. Professors tend to evaluate students' present capabilities to solve a particular set of questions, whereas experienced engineers can evaluate students' potential ability whether the person can cope with unprecedented matters in the future. Work-integrated Learning based on part-time work during the studies enables develop co-evaluation methods shared by professors and experienced professionals from industry. This is an enriched evaluation method: different points of views are considered during evaluation.

Because of the nature of engineering education and because of the process of growing to be an engineer, rigid pass–fail criteria in terms of digital numbers such as 60% are not recommended. More flexible benchmarking criteria or indicators must be developed. Group evaluation by other students, experienced engineers, and professors might be an alternative.

When NUT sends students to industry through an internship program, faculties visit internship sites and ask industry supervisors to evaluate students from the viewpoint of industry. This practice is still a partial fulfillment of this credo. NUT thinks that this point will become increasingly important in the future. Actually, NUT-associated faculty and staff felt very proud when the graduates of NUT were top-rated by an assessment of personnel affairs experts of Japanese listed companies[22]. Evaluation of educational aspects of university performance requires more input from industry.

[22] NIKKEI (Japan Economic Journal) survey in 2016. See footnote 17.

Chapter 4. GIGAKU SDG Institute

Prehistory

To share and disseminate the GIGAKU paradigm of engineering education and research, NUT decided to launch an annual International Conference series in 2011. The first round of the conference was called for by President Dr. Koichi Niihara.

Message from Conference Chair[23]

Welcome to the website of the first **International GIGAKU Conference in Nagaoka (IGCN)**. The IGCN is designed and organized to provide a cross-border, cross-sector, cross-disciplinary forum for those researchers, educators, and industrial leaders who are creating and practicing GIGAKU in various technology domains in various countries. The first IGCN will be held February 3–5, 2012 on the Nagaoka University of Technology (NUT) campus, the heartland of GIGAKU.

Then what is GIGAKU? Actually, GIGAKU is a term composed of two Japanese word-roots: GI and GAKU. The word GI〔技〕literally stands for all kinds of arts and technology. GAKU〔学〕stands for scientific disciplines in general when used as a suffix. The term was originally coined to describe the fundamental philosophy of education and research of NUT when it was established in 1976. Through this term, the founders of NUT intended to express their recognition that all technical challenges in the real world require a scientific approach. Furthermore, NUT has relentlessly pursued GIGAKU since then.

Thirty-five years have passed. All surrounding conditions have changed dramatically during those years. We are witnessing rapidly globalizing economies and huge scale changes in demographic, industrial, and employment structures. All those changes seem to necessitate the further evolution of GIGAKU. In response to this, NUT recently announced its new “Growth Plan”. A renewed definition of the term is given.

GIGAKU is a science of technologies that gives us an angle to analyze and reinterpret diverse technical processes and objects and which therefore helps us to advance technologies forward. Using a broad range of knowledge about science and engineering, management, safety, information technology and life sciences, GIGAKU provides us with workable solutions and induces future innovations.

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[23] https://sites.google.com/site/igcn2012/

Nagaoka, a birthplace of GIGAKU, is also the birthplace of the legendary tale **"One hundred sacks of rice"**[24], which tells the story of how people of Nagaoka giving the highest priority to education. This tale represents the everlasting spirit of the people of Nagaoka. The organizers sincerely hope that the International GIGAKU Conference organized at this special place will offer a venue at which all GIGAKU practitioners, young and old, coming from different corners of the world but sharing a common dream for GIGAKU, can meet together, strengthen their ties, cross-fertilize each other's imaginations and make further steps toward the realization of their dreams.

November 1, 2011
Koichi Niihara, Conference Chair

Since then presenters from 20–30 international partner institutions of NUT, students and faculties of NUT/KŌSENs, and industry representatives have attended. Up to this year (IGCN2018), more than 125 presentations, from 25 institutions in 17 countries had been presented. Among them, frequently participating overseas institutions have been Chulalongkorn University, Hanoi University of Science and Technology. Universiti Sains Malaysia, Mongolian University of Science and Technology, Guanajuato University, WACE, Mondragon University, Mongolian University of Science and Technology, and the Indian Institute of Technology Madras.

In 2016 February, NUT began to organize another series of International Conference, **STI-Gigaku Conference** (STI stands for Science, Technology and Innovation) at NUT campus. This conference is planned and organized by NUT/KŌSEN students themselves. The topics of the conference emphasized SDGs. Every presenter should declare a specific number of an SDG Goal, which the presenter is seeking to find solutions. It's a kind of **purpose–oriented study experience**. Because the poster presentation space is organized according to goals, the audience can readily review all

[24] The Nagaoka domain suffered great destruction after civil war in Japan in the late 1860s. The neighboring domain provided assistance in the form of one hundred sacks of rice. The rice was intended for hunger relief, but Torasaburō Kobayashi, a chief executive of Nagaoka, proposed a plan to sell the rice and use the money for education instead. Samurai leaders and the famished public initially protested the idea, but Kobayashi appealed, stating that "<u>If a hundred bags of rice are eaten, they are lost instantly, but if they are put towards education, they will become the ten-thousand or one million bags of tomorrow</u>." Kobayashi prevailed. The rice was sold to finance the construction of the Kokkan Gakko school: the earliest modern-day elementary school in Japan.

related research works at a glance in a single room. This series of symposia was also organized annually.

The NUT launched one more series of Symposium in 2017. The symposium is designated as International Symposium on Local Innovative Activation by Food and Energy (**ISLife Symposium**) because of its specific emphasis of life science and food technology. It was intentionally not held in Nagaoka to **encourage participation from remote, not-urbanized regions**, where farming and fishery are still the main industrial activities of the community. The first round was held in Nagashima Town, a small island south-west of Kyushu, in collaboration with Kagoshima KŌSEN. At this symposium, various local community-level efforts to increase potatoe production, to develop chilled fish transportation technologies, and to develop other locally produced technologies and practices were presented. SDGs also played a key role at this symposium. Very soon, NUT will open a satellite campus in Nagashima Town.

Figure 12 STI-Gigaku 2017 (left) and ISLife 2017 (right).

Another program to disseminate knowledge of SDGs to pre-university generations also started in 2017. A team of NUT/KŌSEN students participated in the largest science communication event in Japan, Science Agora 2017, held in Tokyo. The team brought in several **educational tool kits of their creation for school boys and girls**, such as a sort of card game to study SDGs with joy, and paper-made regular icosahedra, each face of which shows SDG goals. The NUT/KŌSEN team has won **Science Agora Award** from the organizer. These tool kits are now downloadable from NUT website;[25] also, NUT faculties are using these tools when they visit local schools.

Through these practices, recognition about the SDGs has spread gradually among participating faculties, students, and industry leaders. This finally engenders

[25] http://www.nagaokaut.ac.jp/j/annai/gic/info/2017_12_07.html

the launch of the new idea of a GIGAKU SDG Institute and engenders more active participation in global initiatives.

The first action is to join the **United Nations Academic Impact (UNAI)**[26]. In fact, NUT applied to UNAI in 2017 March. Our proposal was accepted quickly in June 2017. Recently UNAI offered NUT a role in **UNAI Global Hub for Goal 9** to undertake the following activities.

- build resilient infrastructure
- promote inclusive and sustainable industrialization
- foster innovation

Figure 13 Seventeen Sustainable Development Goals.

Another action is to submit **GIGAKU SDG Institute to UNESCO Chair Program**. UNESCO Chair/UNITWIN Program is the UNESCO's scheme to promote

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[26] The United Nations Academic Impact (UNAI) is an initiative that aligns institutions of higher education with the United Nations in supporting and contributing to the realization of United Nations goals and mandates, including the promotion and protection of human rights, access to education, sustainability, and conflict resolution. Since 2010, UNAI has created a vibrant and diverse network of students, academics, scientists, researchers, think tanks, institutions of higher education, continuing education, and educational associations. There are over 1000 member institutions in more than 120 countries that reach millions of people in the education and research sectors around the world. Since its inception, some 30 international networks of universities and other institutes of higher education and research have endorsed UNAI and encouraged their members to join, representing a global diversity of regions and a thematic wealth of disciplines.
https://academicimpact.un.org/content/about-unai (accessed on 2018/09/27)

global sharing of educational resources and collaboration among universities throughout the world. Managers at NUT chose to use this scheme as a tool to disseminate our idea of GIGAKU education and Sustainable Development Goals to international partners. The next section is the proposed text for that purpose. It was sent to UNESCO in 2017 April. It was finally accepted. UNESCO Secretary General and NUT President Nobuhiko Azuma signed the related document to set up UNESCO Chair for Engineering Education for Sustainable Development in May 2018. The plan, in principle, corresponds to whole educational programs ongoing at NUT, but several modifications would be made to incorporate SDG contents into existing programs.

The Kick-off Meeting was held on October 5, 2018 at the NUT campus with the attendance of representatives from UNESCO and the Japanese National Commission to UNESCO.

Table 5 Milestones of NUT's GIGAKU SDG Institute

yyyy/mm[/dd]	Milestone Event
2001 Sep.	Millennium Development Goals (MDGs) presented by the UN Secretary-General
2012 Feb.	The First **International GIGAKU Conference in Nagaoka (IGCN)** organized. One focus of the conference is GIGAKU Education. IGCN organized it annually since this round.
2016	SDGs were developed to succeed the MDGs which ended in 2015
2016 Feb.	The First **STI-Gigaku Conference** organized at NUT campus, All presenters indicate which SDG goal is the research target. Poster presentations were grouped by goal. XXX KŌSEN-NUT students/researchers presented their findings orally or using posters.
2016 Feb	Prof. M. Ichitsubo contacted UNESCO HQ at Paris and received guidance in how to apply UNITWIN/UNESCO Chair program
2016 April	NUT submitted GUGAU SDG Institute project plan to UNESCO
2016 Oct.	Fifth IGCN First Panel on GIGAKU Education at NUT
2017 Mar.	First International Symposium on Local Innovative Activation by Food and Energy (**ISLife 2017**) held in Nagashima town, Kyushu
2017 May	Prof. Yukawa of NUT and Prof. Aburatani of Kitakyushu KŌSEN attended a conference by a UNESCO Chair in Romania and presented NUT's SDG education tools.
2017 June	NUT became a United Nations Academic Impact (UNAI) member
2017/10/5-6	Second Panel on GIGAKU Education at NUT. Sixth IGCN Second STI-GIGAKU Conference at NUT campus
2018/01/4-7	An overseas intensive training program on SDGs was conducted in Bangkok and Khon Kaen, Kingdom of Thailand
2018/05/18	UNESCO SG and NUT President Azuma signed formal agreement on GIGAKU SDG Institute as UNESCO Chair on Engineering Education for Sustainable Development.
2018/06/13	SDGs information session conducted as a part of faculty development
2018 Sep.	NUT sends application to WACE
2018/10/4-5	Third Panel on GIGAKU Education Kick-off Meeting of UNESCO Chair Program at NUT Seventh IGCN
2018 Oct.	United Nations appointed NUT as UNAI Hub on SDGs Goal 9 – Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

GIGAKU SDG Institute Plan[27]

Summary

Since its inception in 1976, NUT has produced more than ten thousand creative engineers with practical capabilities. The NUT graduates are always top-rated in job placement market. The high reputation and employability of graduates comes from NUT's guiding principles of education, called GIGAKU. Based on this achievement and recognizing the importance of sustainable development requirements for engineers, NUT managers chose to renew its education program under the GIGAKU SDG Institute by fully integrating SDGs into current program structure under the leadership of President Nobuhiko Azuma. NUT will disseminate the concept and good practices of GIGAKU SDG Institute to various parts of the world through its international partnership.

1. Context and justification

For many years, engineers have been taught to achieve such goals as efficiency, cost, quality, performance, etc. of their designed products and services. While these goals remain important for the welfare and happiness of the people, now engineers must be trained to devote attention with great priority to the crucially important goals of global society, represented by SDGs. Engineers are the profession which directly affects the processes of interaction between humankind and nature through products and services they conceive, design, and manufacture. They are responsible for the future of the global society. More importantly they have power to change the mode of interaction. Because of these reasons, engineering education institutes of the world should quickly incorporate SDGs into their education program.

NUT was created in 1976 by the Japanese Government to be a model engineering education institute. Its education program was constructed along with completely new paradigm. The founders have coined the term GIGAKU to describe this paradigm. Since then, NUT has produced more than ten thousand creative engineers. Moreover, it has won the highest reputation and the best employment records among Japanese engineering institutes, as evidenced by many authoritative reports and surveys[28].

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[27] The document was submitted to UNESCO in April 2016. In this chapter, the main body of text is exactly the same as that submitted to UNESCO, but annexes are not included in this memo. In addition, some footnotes are modified or omitted to avoid unnecessary duplication.

[28] See THE World University Ranking 2017 Japanese version, dated March 30, 2017.

Based on this achievement and recognizing the crucially important roles and responsibilities of engineers, NUT managers chose to incorporate SDGs into its education program. For this reason, NUT proposes UNESCO to establish the GIGAKU SDG Institute. NUT will disseminate the concept and good practices to its international partners[29].

2. Objectives

The long-term objectives of the project are summarized as presented below. These are quite coherent with the Strategic Objectives 1, 2, 3, 4, 5 of UNESCO's Medium-Term Strategy for 2014–2021.

1) to develop an education system to foster creative, capable, and responsible engineers
2) to strengthen science, technology, and innovation systems of the country by creating close collaboration between education sectors and industry
3) to build a model of engineering education and to disseminate good practices to participating countries
4) to contribute to the achievement of SDGs

3. Overall structure of the project

GIGAKU SDG Institute offers teaching programs of three types: SDG Engineer Course (Bachelor–Master Program), SDG Professional Course (Master–Doctor Program), and GIGAKU Innovation Program (Joint Master–Doctor Program). Each program has a different combination of learning activities as the table of Structure of Teaching Programs below shows.

[29] NUT has aggressively promoted trans-national education programs, such as Twinning Programs and Double Degree Programs with international partners mainly from economically developing countries. NUT is also offering continuing professional development program for working professionals abroad. These efforts have produced a highly globalized campus and a high ratio of international students.

Table 6 Structure of the GIGAKU SDG Institute

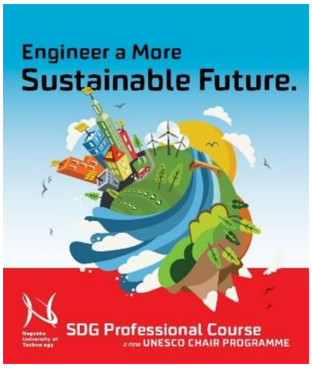
Program \ Type of learning activity	WBL experience	SDG classes	SDG Conference	SDG Research	SDG Planning
SDG Engineer Course Joint Bachelor-Master Program	○	○	○	○	Op
SDG Professional Course Master–Doctor program for working professionals	Op	○	○	○	○
GIGAKU Innovation Program Joint Master–Doctor Program	○	○	○	○	○

Op means optional.

3.1 SDG Engineer Course

The SDG Engineer Course receives both Japanese and international students. The majority of Japanese students are KŌSEN college graduates. They start studying engineering and technical subjects from age fifteen. The course receives undergraduate students from overseas partners under Twinning Program Agreements with eight institutions. During the first half of the bachelor course, the students study at home institutes and then move to GIGAKU SDG Institute to finish bachelor study.

3.2 SDG Professional Course



The SDG Professional Course is a graduate level program designed to give lifelong learning opportunities for engineering professionals who are working as engineers or researchers / teachers in academia. NUT has been offering a Continuing Professional Development (CPD) course since 1994. More than 300 young professionals coming from 15 countries have finished the course to date. The SDG Professional Course is an extension of this course into the area of sustainable development.

3.3 GIGAKU Innovation Program

Since 2015, NUT has been offering a postgraduate course called “GIGAKU Innovation Course”. The course is a joint Master–Doctor program. It gives a student seamless research opportunities extending 4–5 years.

4. Types of Activity

The GIGAKU SDG Institute offers students learning opportunities of five types: Work-Based Learning (WBL) opportunities, SDG Classes, SDG Research, SDG Conference, and SDG Planning. Combinations of these will help students to develop their capabilities to transform their knowledge to solve real-world problems which global societies are facing today.

4.1 Work-Based Learning (WBL) Opportunities

Since its establishment in 1976, NUT has been implementing long-term (5–6 month duration) internship programs as a mandatory component of its bachelor program[30]. Through long-term exposure to the reality of industrial world, the students get a chance to notice what is really needed and also notice what is missing in students' knowledge and skills. Strong motivation to learn is created through this process. This WBL experience has been made possible by the continuing support of industry. Industry is important partners of engineer education. The WBL experience is mandatory for SDG Engineer Course students. Moreover, it is optional for SDG Professional Course students because they have several years of working experience.

4.2 SDG Classes

Students of GIGAKU SDG Institute should take classes specifically emphasizing SDG related topics as a part of their course work.

4.3 SDG Research Project

Supervisors give directions to students for their research work. Supervisors encourage them to devote more attention to local resources and necessities of the local communities. Revitalization of local communities and industries through technological innovation is typical topics to be challenged by the students.

4.4 SDG Conference

Actually, NUT has been organizing a series of international conference (International GIGAKU Conference in Nagaoka, IGCN) at NUT campus and encourages students and faculties to present their research works, best practices of education to international audience. This year, NUT began to organize SDG-focused conferences, STI-GIGAKU in January 2017 and the First International Symposium on

[30] Those students who proceed to graduate school should take a 5–6 month internship before finishing the bachelor program.

Local Innovative Activation by Food and Energy (ISLife 2017) in March 2017. At these conferences, presenters were asked to identify specific SDGs and to present how the presenter's research work contributes to achievement of this goal.

4.5 SDG Planning

Students of the programs must do planning work on how the research output can be transformed into real-world realization through business planning, social venture planning, policy planning exercise, and other forms of endeavors. The SDG Professional Course offers a business planning project. GIGAKU Innovation Course offers MBA learning opportunities in cooperation with the International University of Japan (IUJ)[31]. Various business planning forums and competitions[32] are also provided to students who want to execute an idea and plan.

5. Visiting professorships

Through the project, NUT and partner institutes will have chances to exchange faculty members as visiting professors on full-time and part-time basis. Intense and continuing exchange of faculty members is expected to contribute to faster dissemination of good practices of member institutions. NUT is pursuing Cross-Appointment scheme with international partners.

6. Institutional development

Through the project, NUT can provide more globalized campus in terms of teaching medium, universal access to campus facilities, country composition of students, and diversity of culture. In addition, faculty and staff members will have more chances to learn more about the needs of international communities.

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[31] The International University of Japan (IUJ) is located in a neighboring town of NUT. The two institutions have set up an arrangement that enables NUT students to get both engineering doctor and MBA titles together during their study at NUT. IUJ offers the only English-based MBA program in Japan listed among the top hundred of the Economist magazine's MBA Ranking.

[32] Teams of NUT students regularly participate in the Japan Business Model Competition (JBMC) and several other competitions. Winners of JBMC participate in global sessions hosted in the USA.

Chapter 5. Proposal for UNITWIN Network

UNITWIN Network

The UNITWIN/UNESCO Chairs Programme was launched in 1992. It just celebrated the 25th anniversary in 2017. As of September 2018, it involved over 700 institutions in 116 countries. It promotes international inter-university cooperation and networking to enhance institutional capacities through knowledge sharing and collaborative work. The program supports the establishment of UNESCO Chairs and UNITWIN Networks in key priority areas related to UNESCO's fields of competence, in education, the natural and social sciences, culture, and communication.

Figure 14 UNESCO Chair Logo of GIGAKU SDG Institute.

UNESCO

United Nations Educational, Scientific and Cultural Organization

uniTwin

UNESCO Chair on Engineering Education for Sustainable Development, Nagaoka University of Technology, Japan

Rapidly changing demands for engineers along with expanding globalization place great importance on harnessing successful practices used in other parts of the world. As stated in MIT's recent report (Chapter 2), a tilting trend is apparent for the global axis of engineering education leadership. Additionally, a trend is apparent for the emergence of a new generation of leaders from engineering education that delivers integrated, student-centered curricula at scale, and which represents further evolution of engineering education in a global arena.

With this realization, we now wish to establish a worldwide coalition of educational institutions and industry.

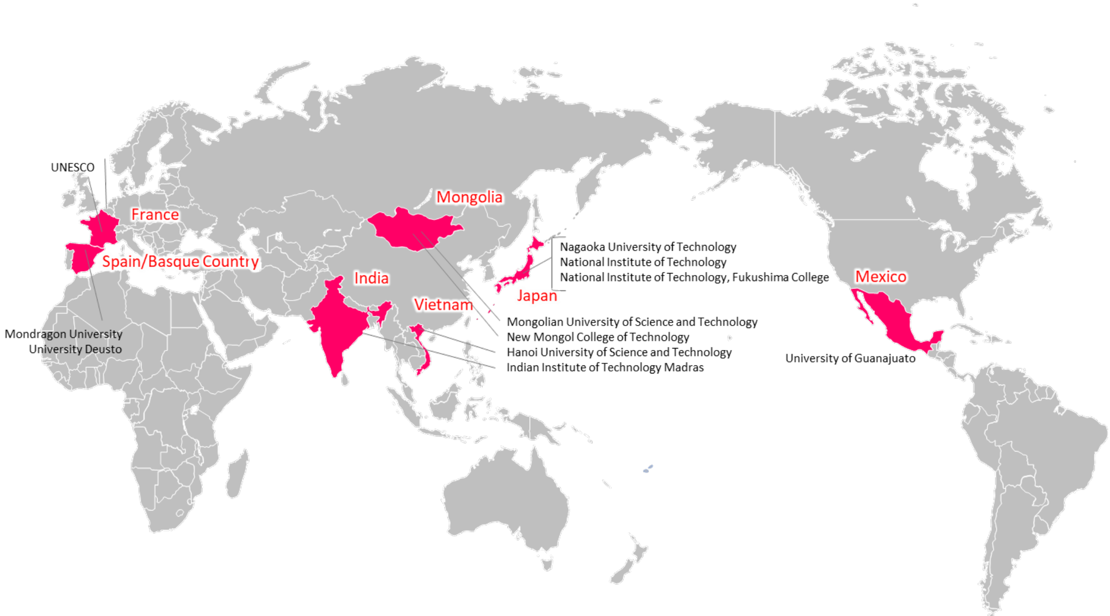
ANNEX I ISCED 2011 levels of education and comparison with ISCED 1997

Level	ISCED 2011	Description	Corresponding ISCED 1997 level
0	Early childhood Education (01 Early childhood educational development)	Education designed to support early development in preparation for participation in school and society. Programs designed for children below the age of 3.	None
0	Early childhood Education (02 Pre-primary education)	Education designed to support early development in preparation for participation in school and society. Programs designed for children from age 3 to the start of primary education.	Level 0: Pre-primary education.
1	Primary education	Programs typically designed to provide students with fundamental skills in reading, writing and mathematics and to establish a solid foundation for learning.	Level 1: Primary education or first stage of basic education.
2	Lower secondary education	First stage of secondary education building on primary education, typically with a more subject-oriented curriculum.	Level 2: Lower secondary education or second stage of basic education
3	Upper secondary education	Second/final stage of secondary education preparing for tertiary education and/or providing skills relevant to employment. Usually with an increased range of subject options and streams.	Level 3: Upper secondary education
4	Post-secondary non-tertiary education	Programs providing learning experiences that build on secondary education and prepare for labor market entry and/or tertiary education. The content is broader than secondary but not as complex as tertiary education.	Level 4: Post-secondary non-tertiary education
5	Short-cycle tertiary education	Short first tertiary programs that are typically practically based, occupationally specific and prepare for labor market entry. These programs might also provide a pathway to other tertiary programs.	Level 5B: First stage of tertiary education: typically shorter, more practical/technical/occupationally specific programs leading to professional qualifications.
6	Bachelor or equivalent	Programs designed to provide intermediate academic and/or professional knowledge, skills and competencies leading to a first tertiary degree or equivalent qualification.	Level 5A: First stage of tertiary education: largely theoretically based programs intended to provide qualifications for gaining entry into more advanced research programs and professions with higher skills requirements.
7	Master or equivalent	Programs designed to provide advanced academic and/or professional knowledge, skills and competencies leading to a second tertiary degree or equivalent qualification.	Level 5A: First stage of tertiary education: largely theoretically based programs intended to provide qualifications for gaining entry into more advanced research programs and professions with higher skills requirements.
8	Doctoral or equivalent	Programs designed primarily to engender an advanced research qualification, usually concluding with the submission and defense of a substantive dissertation of publishable quality based on original research.	Level 6: Second stage of tertiary education (leading to an advanced research qualification).

ANNEX II Founding Members of the GIGAKU SDG Network

The founding members of GIGAKU SDG Network are composed of ten members from six countries. These members are the highly reputed educational institutions of representing countries, and have been the participants of GIGAKU Panel discussions since 2016. All institutions have expressed their commitment to this proposed Network in the form of formal confirmation letter to NUT President.

- Hanoi University of Science and Technology (HUST), Hanoi, Vietnam
- Indian Institute of Technology Madras (IITM), Chennai, India
- Mondragon University (MU), Mondragon, Spain
- Mongolian University of Science and Technology (MUST), Ulaanbaatar, Mongolia
- <u>Nagaoka University of Technology (NUT), Nagaoka, Japan</u>
- National Institute of Technology (NIT), Tokyo, Japan
- National Institute of Technology, Fukushima College, Fukushima, Japan
- New Mongol College of Technology (NMCT), Ulaanbaatar, Mongolia
- University Deusto (UD), Bilbao, Spain
- University of Guanajuato (UG), Guanajuato, Mexico



GIGAKU SDG Network Founding Members and UNESCO

Founding Members of GIGAKU SDG NETWORK

Hanoi University of Science and Technology (HUST)

Hanoi University of Science and Technology (HUST) established in 1956 is a leading public university in Vietnam. Some main data of HUST are:

- 1927 university employees with 1181 teaching staff
- Approximately 29.000 undergraduate students, more than 3.500 graduate students and nearly 1500 international students are being trained at HUST.
- 17 schools, 14 research institutes and centers
- In 2017, HUST is accredited by High Council for the Evaluation Education (HCERES). According to the results of the QS Asia University Ranking in 2019, HUST is rank 260-270
- Having collaborative links with more than 400 universities, institutes and companies from 35 countries globally
- Being institution member of 7 international dynamic networks

In recent years, beside promoting training quality and scientific & technology; HUST has been concentrating on developing student exchange, both inbound and outbound. The number of student exchange at HUST increases 15% per year, reaching 200 international students inbounce and nearly 100 students outbounce in 2017.

Students exchange activities at HUST are undertaken in various forms such as bilateral and multilateral programs. Some key students exchange programs at HUST could be named as bellows:

- Erasmus + KA1 30 partnerships (2015-2018)
- Share Program (2015-2020)
- AUN/SEED-Net Project under JICA support
- Aotule Internaional Network
- Asia Uninet under ACAUninet support
- Shibaura Institute of Technology, Japan
- Temasek Polytechnic, Singapore

These programs have made significant contributions to the development of HUST as one of the leading universities in Vietnam

Founding Members of GIGAKU SDG NETWORK

Indian Institute of Technology Madras (IITM)

Indian Institute of Technology Madras (IITM), established in 1959 by the Government of India, and recognized as Institute of National Importance and Institution of Eminence, holds the No.1 Rank in India issued by the National Institutional Ranking Framework of the Ministry of Human Resource Development for the consequent four years and since inception. Many departments of the Institute are also in Top 100 in the World ranking.

Forty thousand alumini of IITM from its sixteen departments and more than one hundred laboratories serve in many reputed organizations all over the world. About 100 foreign students from different parts of world take courses at IITM every year in different disciplines.

IIT Madras is the preferred choice for the undergraduate and post graduate students who clear the most competitive entrance exams in the world and students from different parts of the country study in this Institute. The institute faculty publishes about 1800 international journal papers in a year and about 250 doctoral students graduate every year. The Institute has more than 150 MoUs with reputed institutes, research laboratories from India and abroad. About 20 reputed Universities from different parts of the World also join hands with IITM and offer joint degree programs.

About 10000 students, 600 faculty and 1500 support staff stay in the residential campus located in the heart of the metropolitan city, Chennai, measuring about 2.5 square kilometer. Chennai, the gate way to South India, is also close to historically important world heritage center, Mahabalipuram, and Golden City of Thousand temples, Kanchipuram.

Founding Members of GIGAKU SDG NETWORK

Mondragon University (MU)

Mondragon University (Mondragon Unibertsitatea in Basque, MU) is a non-profit cooperative private university in the Basque Country, officially established in 1997. It is part of Mondragon Corporation, the world largest cooperatives corporation. Its main campus is in Mondragón, Gipuzkoa. MU has a commitment towards social transformation, which is specified in its participatory model and in its mechanisms to guarantee social accessibility. It is composed of 4 faculties: The Faculty of Engineering, the Faculty of Business Studies, The Faculty of Humanities and Education Sciences and the Faculty of Gastronomic Sciences.

The origin of MU is the Polytechnic School opened by Don José María Arizmendiarrieta [1] in 1943. The Polytechnic School provided the springboard for students of different backgrounds to new jobs. Arizmendiarrieta was intent upon creating a company catering to the positions required by the students graduating from the School. The School and its graduates' community grew along with the industrial development of the Basque Country. Nowadays, Mondragon University is the first Spanish university in technology transfer.

MU's own educational model, based on competencies, involves the companies and institutions intensively in the educational process through the methodology of Problem Based Learning and the combination of work and study by dual educational programmes. "Learn by Doing" is DNA of the university: Reduced classes for active learning methodologies enable to foster personal objectives and expectations and to work cross curricular competencies like multi-communication, problem solving, leadership, etc, The development of the function of "teacher/mentor" in the company, and to teach this new teacher how to accompany the student and to provide feedback to the student along the learning process are key points. At MU, the campus and real world are integrated not only logically but also physically integrated.

NUT has signed MoU with MU in 2015, and exchange of students started in 2016.

[1] Father José María Arizmendiarrieta Madariaga (1915 – 1976) was a Spanish Catholic priest and founder of the Mondragon cooperative movement in the Basque Autonomous Community.

Founding Members of GIGAKU SDG NETWORK

Mongolian University of Science and Technology (MUST)

Mongolian University of Science and Technology (MUST), established in 1959, is a leading state owned Higher Education Institution in Engineering and Technology in Mongolia.

Some main data of MUST are:

- 1,885 university employees with 1,020 teaching staff
- Nearly 21,000 undergraduate students, over 2,500 graduate students and 56 international students are being trained at MUST.
- 11 schools, 4 research institutes, 41 research centers and 42 laboratories
- Having academic collaboration links with over 200 universities and higher education institutions in 21 countries globally.
- Being institution member of 5 international networks
- We have more than 80000 graduates for past 60 years in different Engineering Areas.

Over the past years, MUST has been implementing engineering and technology education reforms to its curriculum and training development under the support from Asian Development Bank, JICA and Mongolian Government.

Academic mobility activities at MUST are undertaken in various forms such as bilateral and multilateral programs. Some key student and staff mobility programs and projects at MUST could be named as follows:

- MJEED project, including the preparation for Japanese KOOSEN Institutes and Twinning Program with 10 Japanese Universities
- CDIO project with Temasek international foundation and Singapore Polytechnic
- Eurasia Pacific UNINET
- IAESTE student exchange
- Erasmus +, 9 partnerships (2009-2019)
- Horizon 2020 EU
- Nagaoka University of Technology, Japan
- Shibaura Institute of Technology, Japan
- Akita University, Japan
- Kitami Institute of Technology, Japan

In the era of the 4th industrial revolution, the internationalization of universities is regarded as a cornerstone of progress and development, and is recognized in global rankings. The university has been widening its collaboration with the world's leading universities in field of Engineering, Technology and Sciences. Due to these programs the development of MUST was able to reach new heights.

Founding Members of GIGAKU SDG NETWORK

Nagaoka University of Technology (NUT)

In October 2018, Nagaoka University of Technology (NUT) was selected as an SDGs hub university (SDG9) in the world. For university initiatives on SDGs, the United Nation Academic Impact has designated one hub university for each of the 17 SDGs. 17 hub universities are expected to acts as models for innovative initiatives related to SDGs.

The fundamental philosophy of education and research of NUT is to inspire and enhance the creative ability of "GIGAKU ~Science of Technology~". We put an emphasis on on-site education and particularly assign student to "Jitsumu-Kunren ~Long-term Internship~", the foundation of the basic concept of GIGAKU education, in workplaces of actual fields for a certain period of time. Through the process of recognizing and experiencing various phenomena and actual situation encountered in actual industrial technology venues, students can fulfill our mission "to cultivate humanity capable of leading engineers and mastering a practical sense of technology through experience."

In recognition of its global, practical engineering education to date, NUT was selected for the "Top Global University project" launched by the Japanese government (MEXT), and has expanded the program to strategic overseas regions to foster the practical engineers with collaboration between partner universities and companies on a global scale.

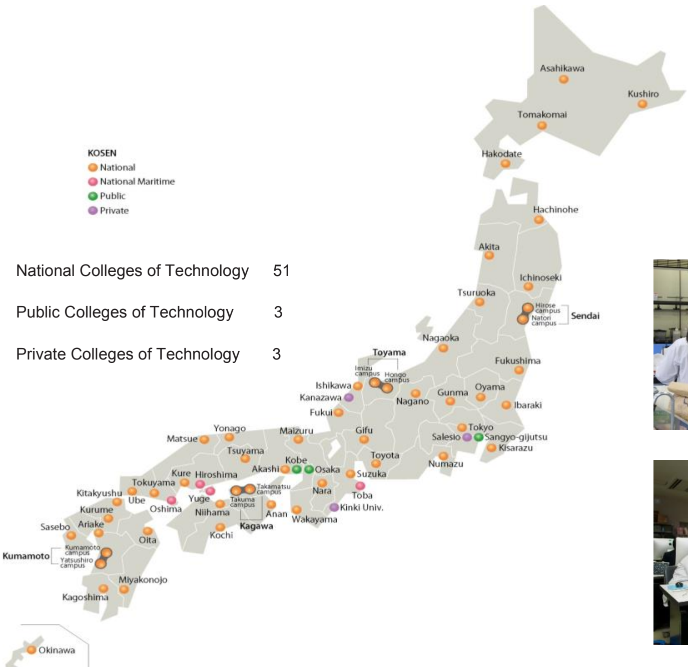
Additionally "Global Pro-Active Root technology Program" was also selected as a "WISE Program (Doctoral Program for World-leading Innovative & Smart Education)" by MEXT. The program is designed to develop excellent human resources who can innovate technology that forms the foundation of all industries based on knowledge of "information engineering," aiming at SDGs, in corporation with universities abroad and enterprises.

NUT produced tough global engineers who have a high level of GIGAKU ability, rich humanity who can accept challenges at the unknown and unexplored research areas, and who can produce technological innovation.

Founding Members of GIGAKU SDG NETWORK

National Institute of Technology (KOSEN)

KOSEN is a unique institution of higher education in Japan, which provides the students with five-year engineering education from the age of 15. The National Institute of Technology (NIT) runs 51 national KOSENs as a single legal entity. NIT has an enrollment of approximately 50,000 students and 4,000 academic staff. KOSEN's primary mission is to foster highly qualified practical and innovative engineers. In this mission, KOSEN also assists the advancement of the industry through joint research projects and collaboration among stakeholders.



Major Academic Fields of Study at KOSEN	
Mechanical & material Engineering	Electrical & Electronic Engineering
Information Technology	Biological & Chemical Engineering
Civil Engineering	Architectural Engineering
Maritime technology	etc.

For more information, please visit the following

Search 「KOSEN」 or URL : https://www.kosen-k.go.jp/

Founding Members of GIGAKU SDG NETWORK

National Institute of Technology (KOSEN), Fukushima College

Fukushima KOSEN has been carrying out the 5-year practical engineering training course for a half century since its opening in 1962, and has produced engineers who are especially required for the needs of the community society.

●学生定員及び現員 Number of Students

学科 Department	入学定員 Allotted Number	現員 Current Student Population 1年 1st Year	2年 2nd Year	3年 3rd Year	4年 4th Year	5年 5th Year	合計 Total
機械システム工学科 Mechanical System Engineering	40	41 (37,4)	41 (40,1)	45 (41,4)	35 (30,5)	41 (40,1)	203 (188,15)
電気電子システム工学科 Electrical and Electronic System Engineering	40	43 (38,5)	44 (42,2)	34 (33,1)	39 (36,3)	42 (37,5)	202 (186,16)
化学・バイオ工学科 Applied Chemistry and Biochemistry	40	40 (20,20)	43 (18,25)	40 (27,13)	40 (25,15)	38 (15,23)	201 (105,96)
都市システム工学科 Civil and Environmental Engineering	40	41 (28,13)	40 (25,15)	40 (24,16)	42 (30,12)	38 (25,13)	201 (132,69)
ビジネスコミュニケーション学科 Communication and Business	40	40 (15,25)	41 (10,31)	43 (8,35)	42 (8,34)	41 (7,34)	207 (48,159)
合計 Total	200	205 (138,67)	209 (135,74)	202 (133,69)	198 (129,69)	200 (124,76)	1,014 (659,355)

専攻科 Advanced Courses	入学定員 Allotted Number	現員 Current Student Population 1年 1st Year	2年 2nd Year	合計 Total
産業技術システム工学専攻 Industrial Technology System Engineering Course	20	33 (29,4)	22 (18,4)	55 (47,8)
ビジネスコミュニケーション学専攻 Business Communicology Course	5	2 (0,2)	2 (0,2)	4 (0,4)
合計 Total	25	35 (29,6)	24 (18,6)	59 (47,12)
研究生 research student	2 (2,0)			
合計在学者数 Total	1,075 (708,367)			

平成31年4月1日現在 As of April 1, 2019 (,)内は(男子,女子)数 (male female)

With the new slogan of "Fostering next-generation engineers who are active at the both local and global level with the aim of achieving sustainable social development," the following four visions will be promoted, as Japan welcomed a new era.

The first vision is “A sustainable society”. This is stated at the beginning of the school's educational goals. The seventeenth recently proposed goal, called SDGs17, is to ensure that all humankind live affluent and happy, and shared by people worldwide. It is being studied by our students to develop human resources who can proceed in the right way in the future.

The second vision is "Global”. In the future, young people who lead Japan are required to play an active role from a global perspective by exchanging information with people around the world or by being able to communicate their opinions firmly at international conferences.

The third vision is "Local". This school was originally developed as a community-rooted school. We will continue to meet local needs.

The fourth vision is "Next-generation engineers”. The society in the future is the "Super-smart society”. It is anticipated that the work that humans have worked on up to now will be involved in AI and IoT technology. In order to survive, we will focus on the three visions described above and to foster engineers who can choose the right path for the era.

Furthermore, this school was selected as a global KOSEN from FY2016 to FY2018. As the host school of JSTS (Japan Seminar on Technology for Sustainability) and ISTS (International Seminar on Technology for Sustainability), we organize both seminars from FY2019 to FY2021. This seminar is focusing on the SDGs17. The seminar aims to foster human resources with ethical standards and a sense of internationality through workshops and various exchange activities among small groups of people.

Based on this educational philosophy and goals, Fukushima KOSEN will continue to develop unique education system and regional cooperation to revitalize education and research, with a view to improve the quality of education through a variety of programs.

Founding Members of GIGAKU SDG NETWORK

New Mongol College of Technology /New Mongol KOSEN (NMK)

New Mongol Kosen is a higher education technology college established in 2014 under the motto "Build your nation yourself" and it uses the model of Japanese Technology College's curriculum system that has 60 years of history. Our goal is to foster creative engineers to contribute to the development of Mongolia, who are healthy, skilled, mastered in the modern industrial technology, as well able to cooperate with other local and foreign engineers.

Some main data of 2019 of NMCT are:

- 50 employees with 40 teaching staff
- 402 students
- 4 engineering departments which are Electrical and electronic engineering, Mechanical engineering, Civil and architectural engineering and Chemical engineering.

In 2019, we had first graduated 53 students. Hereof:

- 11 graduates are working as full-time staff in Japanese companies of technology
- 12 are studying in bachelor degree programs at universities abroad and 4 are Japanese language school in Japan.
- 26 are studying and working in local companies and universities in technology.

Our students have opportunities as:

- Receiving a partial tuition scholarship
- Being awarded a 100% scholarship to study in Japan
- Winning Japanese Government Scholarship
- Being involved in paid internship programs
- Participating in contests as "ABU Robocon" and "Deza-con" to improve engineering skills
- Participating "Sakura Science" program
- Participating "Genesys" program

We are delighted to produce graduates who have strong communication skill with people and technology, problem-solving ability, positive attitude, and high professional competency for the society and industrial development.

Founding Members of GIGAKU SDG NETWORK

University of Deusto (UD)

The University of Deusto **was inaugurated in 1886**, in Bilbao, a seaport and commercial city which was undergoing considerable industrial growth during that era, and was chosen by the Society of Jesus, as the ideal location. Nowadays, Bilbao is the centre of a metropolitan area with more than one million inhabitants, a city traditionally open to Europe. It is also an important harbour and a commercial and financial centre in the north of Spain. The central headquarters of the University of Deusto is located by the river Nervión, facing the city icon, the well-known Guggenheim Museum.

The University of Deusto aims to serve society through its contributions with a **Christian approach to today's realities**. As a university, its guidelines are love of wisdom, desire for knowledge and rigour in scientific research and methodologies. Therefore, its main focus is on achieving **excellence in research and education:** Educating free citizens, who are responsible and competent professionals, equipped with knowledge, values and skills, and committed to **foster learning and transform society.**

The current strategic plan, namely **2022 Deusto Initiative**, reflects the ambition of the institution, through its motivational motto: **Transforming the World Together**.
This plan is based on two closely-related inspiring principles: the **Ignatian identity**, and **social and environmental responsibility** (the specific contribution of our university). The plan addresses three cross-sectional axes: **internationalisation, digitalisation, and diversity**, which will be embedded in all actions, and will permeate the university's activities. The Plan also establishes a goal: the **United Nations 2030 Agenda**, to be used as a roadmap for the sustainable development of the planet. The University's alignment with this worldwide challenge and its effective incorporation into Deusto's strategic plan will make it possible to monitor Deusto's contribution to the 17 SDGs.
Transforming the World Together - people and institutions, together, generating alliances and networks. We got here together. We shall win the future together.



Founding Members of GIGAKU SDG NETWORK

University of Guanajuato (UG)

The University of Guanajuato is a comprehensive, multi-campus university, ranked 4th among public (state) universities in Mexico, and 2nd best for international outlook, according to the Times Higher Education World University Ranking in 2019. A major research institution with 115 graduate and 92 undergraduate programs in the fields of Arts, Health Sciences, Economics and Administration Sciences, Natural and Exact Sciences, Social Sciences and Humanities, Life Sciences, and Engineering. UG has a total enrollment of 27,937 students, in 4 Campuses across Guanajuato State, organized in 13 Divisions. The UG High School System has 15,214 students in 11 venues in the state of Guanajuato.

UG has 331 laboratories and over 588 researchers who have been recognized by the National System of Researchers of the Mexican Council of Science and Technology (CONACyT). Research is conducted in 114 Academic Groups creating an ideal environment for knowledge production, management, and technology transfer. UG also organizes every year its Summer Research Program, recognized internationally for its quality, for undergraduate and graduate students.

In terms of international collaboration, the university welcomed 915 international students, 309 international mobility students and 286 international degree-seeking students (3.4% of total students' body); a total of 214 visiting during the academic year 2017-2018. UG has 327 international agreements with 202 international partners in 35 countries. It offers double degree programs at the undergraduate and graduate level with institutions in Europe (FH Dortmund, Universidad de Girona) and Asia (Hiroshima University and Nagaoka University of Technology). UG participates in international collaboration through different networks such as Erasmus+, 100K Strong in the Americas, to name a few. Short-term Spanish language and cultural programs are tailored to the needs of foreign universities upon request.

ANNEX III THE GIGAKU SDG NETWORK BYLAWS

(Adopted as a part of the GIGAKU Panel Report)

ARTICLE I – NAME

The name of this network shall be The GIGAKU SDG NETWORK, hereinafter referred to as the Network.

ARTICLE II – PURPOSE

1. The objective of the Network shall be to serve as a forum for the continuous improvement and development of engineering education practices which help global society to achieve sustainable development goals (SDGs).

2. The Network works under the UNESCO's UNITWIN framework and shall maintain close contact with UNESCO and the relevant UNESCO Chairs.

ARTICLE III – MEMBERSHIP

1. Any higher educational institution, research institution, and industrial partner which shares the credos given in the GIGAKU Panel Report (discussed at the third panel on GIGAKU on October 4, 2018 and which were adopted in the follow-up communication) may become a Network member.

2. No financial contribution is necessary to become a Network member.

3. New membership will be accepted when an application request from the applicant is regarded as appropriate by a majority of members. The application request is expected to state the principles and practices of engineering education of the applicant institution and supporting/endorsement message to the credos given in the GIGAKU Panel Report. There is no fixed format for an application request. Its length shall be less than five pages.

4. Each member shall be entitled to cast one vote on all matters which come before a meeting of the Network.

5. Founding members are listed in the ANNEX to these Bylaws.

ARTICLE IV – ANNUAL MEETING

1. Members meet on a face-to-face basis at least once a year. Any member can voluntarily host it at its home. The host, venue, and date for the next year's meeting are determined at the annual meeting. The local costs of the annual meeting shall be borne by the host.

2. Nagaoka University of Technology (NUT) is prepared to host it in the event that no other candidate is chosen.

3. A chairperson nominated and chosen at the opening of the meeting presides over the annual meeting.

4. At the annual meeting, members share good practices of their own and relevant useful information for members. Voluntary submission of teaching materials or other forms of educational resources that members are ready to share with other members will be welcomed.

5. At the annual meeting, members discuss issues of common interest and express views and opinions of the Network to the public.

6. The institution hosting the annual meeting shall send an invitation to the UNESCO contact point and to relevant UNESCO Chairs.

ARTICLE V – TEAM OF REPRESENTATIVES, COORDINATOR

1. Planning, operation, and review of the activities of the Network are managed by a team comprising representatives nominated by the members.

2. Representatives communicate through electronic mail and/or documentary means between annual meetings. A chairperson is nominated annually by the team.

3. A coordinator assigned by the hosting institution of the next annual meeting shall facilitate communication of the team until the annual meeting.

4. A coordinator prepares an agenda for the annual meeting, and compiles activity reports to UNESCO as a UNITWIN network when necessary.

5. Initially, NUT is prepared to assign a coordinator for the first annual meeting.

ARTICLE VI – AMENDMENTS TO BYLAWS

The bylaws may be amended, in whole or in part, by a two-thirds vote of those present at a meeting of the Network provided that the meeting notice includes specific notice of intention and provided that a summary of the proposed change/changes is included.

ANNEX Founding Members of GIGAKU SDG NETWORK

- Hanoi University of Science and Technology, Vietnam
- Indian Institute of Technology Madras, India
- Mongolian University of Science and Technology, Mongolia
- Nagaoka University of Technology, Japan
- New Mongol College of Technology, Mongolia
- National Institute of Technology, Japan
- National Institute of Technology, Fukushima College, Japan
- Mondragon University, Spain
- University Deusto, Spain
- University of Guanajuato, Mexico

長岡技術科学大学
Nagaoka University of Technology

GIGAKU PANEL REPORT Vol.1

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United Nations
Educational, Scientific and
Cultural Organization

UNESCO Chair on Engineering Education
for Sustainable Development,
Nagaoka University of Technology, Japan

GIGAKU SDG Institute

長岡技術科学大学
Nagaoka University of Technology