

On Partnerships between High Schools and Universities for Mathematical Sciences Education

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It is understood that the number of students who come to dislike science and mathematics increases as students age. Classes that stimulate intellectual inquisitiveness and inquiring minds are important in order to increase the number of students who are interested in science, arithmetic, and mathematics. However, as globalization gathers speed for the international economy of the 21st century, it is of great necessity to continuously develop global human resources who possess communication skills, intercultural experiences, and mathematical ways of thinking. There is a compelling need for high schools and universities to develop and train global talent for employment opportunities in the government and companies. Therefore, the purpose of this paper is to clarify the capabilities and conditions of global human resources and to propose such talents can be developed in both high schools and universities in Japan.

Key words: Global, Mathematical Cooperative Education, High School, University, Japan, Thailand

1. Foreword

The basic objective of “The Second Basic Plan for the Promotion of Education” [1] is the enhancement of science and mathematics education in Japan.

This plan states, “regarding the motivation to learn, some students improved, but elementary school students’ interest in arithmetics and junior high school students’ interest in mathematics and science are weaker than the international averages.”

Meanwhile, due to the current entrance examination system, most senior high schools have no choice but to teach mathematics as a subject to be memorized. Students also see mathematics as a subject to be memorized and as they are studying mathematics in order to get through the entrance examinations, hostility and disdain towards mathematics is spreading among the general population. For this reason, senior high school teachers wish that they could somehow make the students experience the joy of thinking through mathematics. However, as mathematics class hours are limited at junior and senior high schools, the current situation is that it is not possible to satisfactorily stimulate intellectual inquisitiveness and inquiring minds.

Consequently, it is difficult to hold classes or seminars that make it possible to both stimulate the intellectual inquisitiveness and inquiring minds of students who have no interest in mathematics and extend the abilities of those who are interested.

However, one way to make it possible to both stimulate the intellectual inquisitiveness and inquiring minds of students who have no interest in mathematics and extend the

abilities of those who are interested is the Japan Mathematics Contest (JMS) [2].

The parent body of the JMS is the Meeting for Mathematics Education which brings interested university and senior high school mathematics teachers from the three prefectures of the Tokai region together. It has been held since 1990. The competition sets problems with no solutions and asks entrance examination candidates to find problems themselves and it is possible to observe extremely unique problem setting (see Appendix A). This competition has the aim of cultivating human resources with superior mathematical thinking skills, inquiring minds and creativity.

Follow-up seminars are held for prize winners at the mathematics competition but recently, these have also been opened up as lecture meetings for the general public. This initiative stimulates the 1991 Central Council for Education report entitled Reforms of Various Systems in Education to Make Them Relevant to a New Age and is linked to the Ministry of Education pilot project on exceptional measures in education put in place from 1994. In addition to Nagoya University, 9 other institutions, including the Kyushu Regional Mathematics Education Society, held extension lectures and seminars, accepted students for course subjects and implemented mobile guidance.

Furthermore, the Ministry of Education, Culture, Sports, Science and Technology-Japan is actively conducting various initiatives such as designating senior high schools that implement advanced science and mathematics education as Super Science High Schools (SSH) in order to cultivate human resources involved in international science and technology in future challenging research that makes good use of classes according to unique curriculums, cooperative education between senior high schools and universities and lo-

cal characteristics based on plans created at each school in order to cultivate human resources in science and technology. SSHs were started in 2002 and, as of 2016, 200 schools had been designated. The main functions of SSHs are cooperative education between senior high schools and universities, curriculum development, overseas cooperation, international exchange and challenging research.

As the aim of SSHs is to cultivate international science and technology human resources, the globalization of the economy and society has been advancing in recent years. Environmental issues, financial crises and energy issues are not only the problems of a single nation or people, the trend of these being challenges on a global scale is increasing and the wave of globalization cannot be avoided. However, currently Japan has an insular environment as shown by its geographical position and such terms as the Galapagos Phenomenon [3] in the mobile telephone business. This is why there is demand for clear meaning of existence and changes in ideology in Japan and the international society of Japanese people in terms of a globalized society. In this way, in our modern era not only of globalization but also of intensified global competition, it is important to cultivate Japanese people who can work on the world stage.

However, looking at the results of surveys over recent years, the recent ambition of university students and young company workers to study [4][5] or find work [6] overseas is low. The main reasons for this are lack of language skills and anxiety about the lifestyle overseas. Another reason is that more than half of those who want to study or work abroad want to go to developed countries such as America or countries in Europe and the ratio of people who want to go to emerging nations or developing countries is low. Meanwhile, approximately 80% of Japanese companies responded that they should be progressing with globalization in the future [6] and had a sense of impending crisis with respect to globalization. In this way, it can be said that, despite the awareness of crisis among Japanese companies with respect to globalization, the current status in Japan is that there are few human resources who can respond to globalization.

The yen strengthened after the Plaza Agreement of 1985 and the advance of Japanese companies into overseas markets was activated in a full-scale manner. Despite the majority of overseas expansion from the latter half of the 1980s to the 1990s being to Europe and America, there is remarkable recent overseas expansion into Southeast Asian countries such as Thailand. In addition, along with not only the overseas expansion of large companies but also of small and medium companies and client companies and an increase in overseas demand, there is an increase in expanding into overseas markets [7][8].

A big challenge in the overseas expansion of Japanese companies is the cultivation and securing of global human resources. However, along with the increase in overseas expansion of companies, the cultivation of global human resources has become urgent. In addition, it is difficult to cultivate global human resources in small and medium companies. For that reason, it is urgent to cultivate global human resources at universities who can be responsible for the international expansion of companies. However, compared to

overseas universities, Japanese universities are not making progress with globalization as they have low ratios of teachers and students of foreign nationality. In addition, it has been pointed out that there is an increase in introverted students at Japanese universities demonstrated by the decrease in the number of students who study abroad and the increase in the number of students who have no wish to work abroad.

The definition of global human resources and human resources taking the global situation into account differ depending on the company and the university but human resources that fulfil elements I–III demonstrated by the Global Human Resources Cultivation Promotion Council are defined as global human resources. Element I is defined as language skills and communication abilities, Element II as individuality, assertiveness, spirit of challenge, cooperativeness, flexibility, sense of responsibility, sense of responsibility and sense of duty and Element III as understanding of foreign culture and the Japanese identity [9].

Based on this current situation, along with the increase in the expansion of Japanese companies overseas, with the aim of cultivating and securing global human resources, improving international industrial competitiveness and strengthening the ties between countries, movements for the cultivation of human resources such as the Ministry of Economy, Trade and Industry index survey [10] on cultivating global human resources at universities and the Ministry of Education, Culture, Sports, Science and Technology-Japan/Japan Society for the Promotion of Science project to promote global human resources cultivation [11] are gathering speed.

Furthermore, approaches from scientific fields such as focusing on environmental issues and big data are indispensable. In particular, there is demand to understand a mathematics/informatics society and cultural positioning and to form and provide education curriculums that make it possible to acquire wide-ranging and deep academic knowledge. Consequently, through mathematical cooperative education, based on logical thought, flexible concepts and deep insight, it is necessary to foster abilities that transmit and cooperate globally.

Up until now, Japanese higher education has had a stable market domestically and there has also been a high-level of technological skills focused at national universities. However, the insularity of the Japanese education system and the delay in internationalization have been pointed out along with the wave of globalization. Consequently, focusing on the Ministry of Education, Culture, Sports, Science and Technology-Japan, the improvement of foreign language education, understanding of foreign cultures and the internationalization of education such as overseas student policy is progressing in junior and senior high schools. In particular, there is activation of international exchange with geographically close ASEAN (Association of South-East Asian Nations) countries.

In recent years, the governments of each ASEAN country are progressing with the active internationalization of higher education involving domestic higher education institutions in each country. In the various ASEAN countries, based on the characteristics of each country's higher education and systematic and cultural backgrounds, vari-

Table 1. No. of school attendees in Thailand.

Classification	National (people)	Private (people)	Total (people)
Pre-school education	1,222,262	591,276	1,813,538
Primary education	4,010,832	981,003	4,991,835
Lower secondary education	2,308,931	353,339	2,662,270
Upper secondary education	1,692,121	417,752	2,109,873
Higher education	2,011,353	365,866	2,377,219

ous higher education quality assurance systems have been established in each country. However, with the ASEAN Economic Community (AEC) concept, there is activation of exchange in higher education and activities that aim for mutual development. For example, there is not only expansion of the AIMS (ASEAN International Mobility for Students) programme which is a student exchange support project organized by ASEAN countries and the movement for the construction of a quality assurance framework common to all ASEAN countries focusing on the ASEAN Quality Assurance Network (AQAN), but also a great variety of internationalization such as the creation of international education and research bases, exchange agreements between universities, the formation of consortiums and collaborative degree programmes. Furthermore, Japan has maintained a close relationship with ASEAN ever since it was established and in recent years, emphasis is being placed on ASEAN as shown by the announcement of the Abe Doctrine (5 general diplomatic rules with respect to ASEAN). Among these ASEAN countries, Thailand is an ASEAN hub in geopolitical terms and as it has a good infrastructure, many Japanese companies have expanded into the country and there are also many political and economic links. In recent years, there has been a dramatic increase in cooperation between Japanese and Thai universities. For this reason, by furthering understanding about cooperation with and internationalization of higher education in Thailand, there are many instances in which Thailand is a reference when considering cooperative education and internationalization in Japan.

Therefore, this study, based on the present state of higher education and mathematical education in Thailand, discusses the study and practice of mathematical cooperative education in Japan from an international perspective.

2. The Thai Education System

2.1 The Thai education system

The Thai education system uses, in the same way as Japan, the 6-3-3-4 system: 6 years of primary education (elementary school), 3 years of lower secondary education (junior high school) 3 years of upper secondary education (senior high school) and 4 years of higher education (university). Compulsory education is 9 years from primary education to the end of lower secondary education. It should be noted that after 3 years at junior high school are completed, it is possible to go on to a vocational school (3 years).

The National Education Act was established to govern education. In addition, Thai education administration is governed by the Ministry of Education which has cen-

Table 2. TQF.

TQF1	Standard qualification of program
TQF2	Program/Curriculum
TQF3	Course specification
TQF4	Field experience specification
TQF5	Course report
TQF6	Field experience report
TQF7	Program report

tralised authoritarian rule unlike Japan. For this reason, the Ministry of Education establishes and manages schools in a unified manner (it approves private schools) and either state or private schools are established. There are no public schools (established by prefectures, towns or villages) as in Japan.

School attendance as of 2011 was 76.8% for pre-school education, 103.5% for primary education, 98.4% for lower secondary education, 72.2% for upper secondary education and 47.2% for higher education [12].

2.2 Higher education in Thailand

Higher education consists of integrated universities (4 years), Rajabhat universities (4 years) and professional technical schools (2–3 years or 4 years). Rajabhat universities were formerly institutes with the aim of training teachers. These institutes became community integrated universities in 1992 and then became Rajabhat universities. In addition, there are 2 public universities where it is possible to attend without taking any examinations with the aim of providing broad higher education opportunities to people: Ramkhamhaeng University (approx. 360,000 students) and Sukhothai Thammathirat University (approx. 160,000 students) (Table 1).

There were 78 national universities (27 integrated universities, 2 public universities, 40 Rajabhat universities and 9 Rajamangala universities of technology) and 69 private universities in Thailand as of 2011 but there is an annual increasing trend in the number of universities due to the increase in the number of people entering higher education.

The national university entrance examination system, CUAS (Central University Admission System), has been in place since 2006. This system determines passes or fails depending on 1) senior high school results (High school cumulative grade point average (GPA)), 2) results of national examinations held in the February of 3rd year at senior high school (Ordinary National Educational Test (O-NET)), 3) results of general subject examinations held in October and

March (General Attitude Test (GAT)) (multiple choice) and 4) results of elective subject examinations held in October and March (Professional Attitude Test (PAT)) and the ratio of 1)–4) differ depending on the university or the department. It is different from the Japanese university entrance examination system in that it is structured so that the majority of Thai national universities do not hold their own individual examinations and students who are taking entrance examinations choose 4 universities in which they are interested and then they wait to hear from the university whether they have been successful or not. In addition to the CUAS admissions system, there are various other admissions systems including recommendations and scholarships. Furthermore, the private university admissions system is entrusted to each university and entrance examinations are generally written examinations.

3. The Present State of Education in Thailand

3.1 The present state of higher education in Thailand

Due to the increase in the rate of advancement to higher education and the number of universities since the 1990s, Thai universities have transitioned from elite institutions to mass institutions. Due to the increase in the so-called middle class in Thai economy, currently, approximately 70% of senior high school graduates aim to go on to university and the total number of students in higher education exceeds 2 million. Conversely, there is concern that the rapid increase in universities and student numbers will lower the academic abilities of the students being admitted and lower the quality of higher education. Meanwhile, there are cases in which independent rules at each higher education institution are reducing teacher ambition to teach and the learning effects of students who are being educated (e.g. maximum number of print outs for one lecture).

Higher education policy is changing based on the current state of affairs. Current higher education policy in Thailand implements the 12th National Economic and Social Development Plan (2017–2021) and the 2nd 15-year Long Range Plan on Higher Education for Thailand (2008–2022) and the main challenges are: 1) improvements in the quality of education through education reform, 2) creation and securing of equal education opportunities, 3) strengthening teacher abilities, 4) formulation of an education curriculum based on the needs of the labour market, 5) securing international competitive strength through implementing education that makes use of IT, 6) improvements in the research environment and 7) responding to AEC.

In addition, with the aim of improving quality and homogenizing higher education, the TQF (Thai Qualifications Framework for High Education) curriculum standards and evaluation were set in 2009 and applied to new students from 2012 onwards. University syllabuses are reviewed every 5 years to confirm if they conform to TQF. TQF evaluates 5 categories: 1) ethics and morals, 2) knowledge development, 3) intellectual development, 4) personal relations/self-responsibility and 5) mathematical thought/communication abilities/IT skills. In addition, as shown in Table 2, TQF has stages 1–7. TQF2 equates to evaluation standards for each major subject, TQF3 to syllabuses for each lecture and achievement objectives and

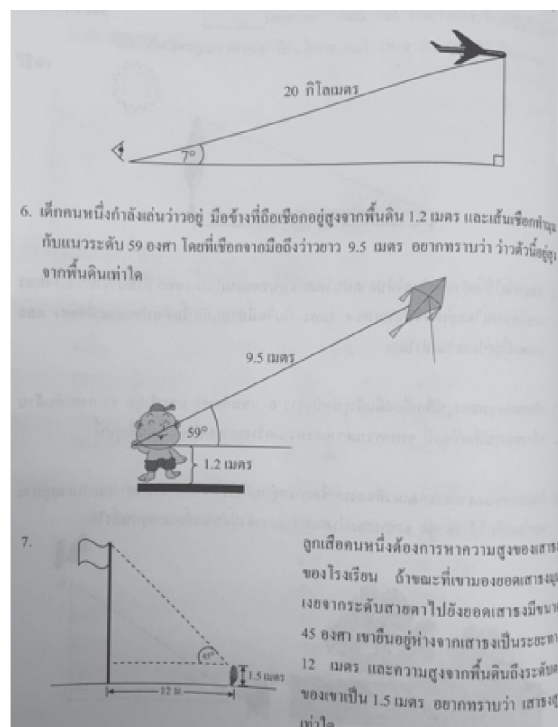


Fig. 1. Example of Thailand mathematics textbook (1st year of senior high school).

TQF5 to an evaluation report for each lecture. However, the current situation is that evaluation by TQF is losing substance.

Furthermore, since August, 2014, in order to facilitate overseas study between ASEAN countries, higher education institutions term commencement has been unified and the system which used to consist of two terms from May to September and November to March has been changed to two terms from August to December and January to May. Meanwhile, the two terms for education of secondary level

and below remain the same from May to September and November to March. In addition, the fiscal year remains as it was from October to September for both higher education institutions as well as education of secondary level and below. For this reason, in this present state, the difference between term time for senior high schools and universities and the difference between the fiscal year and the academic year have become issues.

3.2 The present state of mathematical education in Thailand

Senior high schools in Thailand provide 5 hours of mathematics classes a week giving a total of 200 class hours a year (40-week year). The full-time Japanese general education curriculum for senior high schools provides 4 hours of mathematics classes a week giving a total of 140 hours a year (35-week year) [13]. Therefore, Thailand provides more mathematics class hours than Japan.

The contents of senior high school education are: power index calculation, measurement problems using trigonometric ratios, sequences (arithmetic progression, geometric progression), statistics (averages, variance, distribution, etc.) and quadratic equation with one equations (Fig. 1). The tendency towards practical content is high compared to mathematics at Japanese senior high schools.

Science and mathematics education in Thailand is facing two issues. The first of these is the decrease in numbers and quality of teachers and the second is the issue of educational materials. These problems are most remarkable in elementary schools. Most elementary school teachers graduate from humanities departments and there are few who graduate in science and mathematics subjects. In addition, there are almost no study materials which communicate how interesting science and mathematics are. As a result, most children and students lose interest in mathematics and science and there is a strong trend in which students find these subjects difficult.

As a result, when senior high school students go on to university (higher education institutions), as they feel that science subjects are more difficult than humanities subjects, there is a strong trend among most senior high school students going on to study in humanities departments. Consequently, Thailand is progressing with the cultivation of teachers who can stimulate children's' and students' interest in science.

Furthermore, special programmes are being implemented with the establishment of Mahidol Wittayanusorn Schools, Chulabhorn Science Schools and science schools affiliated to universities in the same kind of system as the Japanese SSH system. For example, the Demonstration School, Faculty of Education, Prince of Songkla University (Satit PSU) is a science school affiliated to a university with 11 designated schools and 1 science class (around 30 students) has been established in each year group. In addition, Satit PSU produces excellent results with O-NET integrated results being in the top 1% in Thailand. The university-affiliated Satit PSU science school holds special lectures and experiments at the university department of science and engineering and implements special curriculums and trips to overseas universities (international exchange). In particular, there is an intention to have as many students as possible

experience international exchange within geographical conditions and a limited budget and exchanges with Japanese universities are being conducted.

3.3 The present state of regional education in Thailand

In Thailand, there are various inter-regional discrepancies in economy and income between some large cities (urban areas) such as Bangkok and Chang Mai and regional cities which are not in urban areas (regions). In particular, the income divide in Thailand which began in the 1970s has rapidly expanded due to an overconcentration of economic growth in Bangkok and is a serious problem today. The gap between Bangkok and the north and northeast is particularly wide. Military coups d'état that occur frequently in Thailand occur mainly due to this income divide.

In general, there is a strong correlation between education levels and this income gap and there is a trend in which the higher the education level people have, the higher their wages are likely to be. For this reason, it is considered that, if regional education levels are improved, the income divide with urban areas will decrease. However, even though regional education is being enhanced every year, the issue of the income divide remains a big problem.

In addition, there are regional differences in the education field such as differences in educational levels between urban areas and regional areas and a lack of teachers. For this reason, in order to rectify the lack of teachers and raise the level of education, university teachers are being dispatched to senior high schools, science and mathematics seminars are being held and presentations on university education contents and curriculums are being made. In addition, as part of internationalizing education, there are cases in which foreign university teachers teach at university-affiliated senior high schools. Meanwhile, as there are enough teachers and it is easy to get hold of information in urban areas, apart from university-affiliated science schools and some university-affiliated senior high schools, there is no cooperative education between senior high schools and universities as there is in regional areas.

4. Study and Practice in Mathematical Cooperative Education from an International Perspective

In our currently globalizing world, internationalization and international perspectives cannot be avoided. For this reason, both Japan and Thailand are progressing with internationalization. Many MoUs (Memorandums of Understanding) between universities in Japan and universities in South East Asia focusing on Thailand are being concluded. In addition, some universities in Japan, cooperation with various universities in South East Asia such as having offices in Bangkok is being strengthened. Meanwhile, these networks are links between higher education institutions and universities but these benefits are not spreading to senior high schools. However, from the point of view of broadening the outlook of students, giving them a sense of purpose and providing them with stimulation, it is extremely beneficial to cooperate with university research laboratories from the senior high school stage and to cooperate with high schools overseas. As examples of international exchange at SSHs, there is joint distance learning with senior high schools in Thailand using a video-conferencing



Fig. 2. A lump of snow collected on a license plate (schematic diagram).

system [14]. Therefore, through overseas university networks managed by universities, cooperation and international exchange with overseas university-affiliated senior high schools is conducted and by conducting mathematical cooperative education from an international perspective, it is possible to cultivate international human resources in science and technology. In addition, as is done at SSHs, by conducting cooperative education not only for students at specified senior high schools but also for senior high school students leads to the cultivation of students who have a talent and the improvement of ambition. Furthermore, the reach of mathematical education as well as improvements in academic ability within the prefecture is extended by having senior high school teachers within the prefecture participate.

Looking back over the modern history of Japan, since the Meiji Restoration, Japan has actively incorporated Western civilization from Europe and America and has followed the path of modernization. Following that, Japan went through the Second World War which brought it up to today. In addition, among the issues in Japan after losing the Second World War, it was mainly America that promoted reconstruction and the cooperative relationship with America continues to the present day. For this reason, understanding of foreign culture has been aimed at understanding the cultures of Europe and America. Furthermore, as there is a strong relationship between Europe and America and modern Japan, there has been a tendency to be biased towards focusing on Europe and America in junior and senior high school education. However, from this era onwards, growth is expected not only in Asia but also in Africa and Central and South America and it will be essential to understand foreign cultures on a global scale rather than focusing on Europe and America. Of these, Thailand is a pro-Japanese country and in addition, its native language is not English therefore it can be considered suitable as a first step to overseas exchange as there are few hurdles to overcome.

Many countries in Asia, Africa and Central and South America lack human resources, information and budgets. Meanwhile, as future development of cities and economies can be expected, there are also great expectations of mathematics and science. For this reason, the perception and concepts of mathematics and science are different to those of Japanese people. For this reason, conducting exchanges with Thailand is a good opportunity to broaden outlooks as it is possible to come into contact with a culture and sense of values that is different from Japan such as topography, ethnic groups and social situation. In addition, it is considered that, through this experience, there is a good influence on



Fig. 3. A part of an iceberg drifting in the Antarctic Ocean. A repeating pattern of the structure in Fig. 2 can be seen.

the attitude to mathematics and science and the concept of pursuing further education. In addition, it is considered that conducting activities along with local people with different cultures and customs creates foundations for accepting diverse cultures makes it possible to develop flexibility that can respond to global society in the future.

5. Conclusion

Initiatives to cultivate students who are interested in science, arithmetic and mathematics are being conducted not only in Japan but also in various other countries. This is also a manifestation of the expectations of the field of mathematics and sciences in each country. In addition, in the same way, initiatives in education that respond to globalization (internationalization) are being implemented. In particular, for countries that lack natural resources such as Japan, the cultivation of excellent human resources is important. Furthermore, taking the present state of Japan into account, the cultivation of human resources in science and technology who can be active on the international stage will become even more important in the future. For this reason, initiatives such as mathematics competitions and cooperative education between senior high schools and universities are important.

In addition, by conducting mathematical cooperative education from an international perspective, international exchange with overseas universities and senior high schools is promoted and if the number of overseas senior high school students who are interested in Japanese universities and culture increases, there will be an increase in students who wish to attend Japanese universities and with that, secondary effects such as the acceleration of internationalization of universities and the expansion of the international exchange network can be expected. In order to widen activities such as mathematics awareness programmes for Japanese youth and aiming for the improvement of mathematics skills to a national level, it is essential to increase the number of cooperating university research institutions in the future.

Appendix A. An example of question of JMS [15]

Question: Tent-like lump of snow

While driving a car in a snowstorm, snow blows onto the license plate and gets collected on the plate in the shape of a tent, as shown in Figs. 2 and 3. Please consider the factors that could give rise to the formation of such a shape.

Explanation: Tent-like lump of snow

Snowflakes are letters from heaven (taken from “Ukichiro Nakaya Essay Collection” edited by Ikeuchi Satoru).

With mathematics, we can use models to describe this natural phenomenon. This problem is an inverse problem that seeks how the “letters” that we see in nature (the input and output) are formed (the model). In this math contest, we actively adopt these types of problems and are known for it. This type of problem can be seen in Problem 4 of the 1st Contest (the growth of yeast bacteria), Problem 4 of the 2nd Contest (the milk crown shape), and Problem 4 of the 8th Contest (video mosaic), which deals with the restoration and completion of an unclear picture.

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