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Approaches to Fostering 21st-Century ICT Capabilities for Future Generations in APT Countries

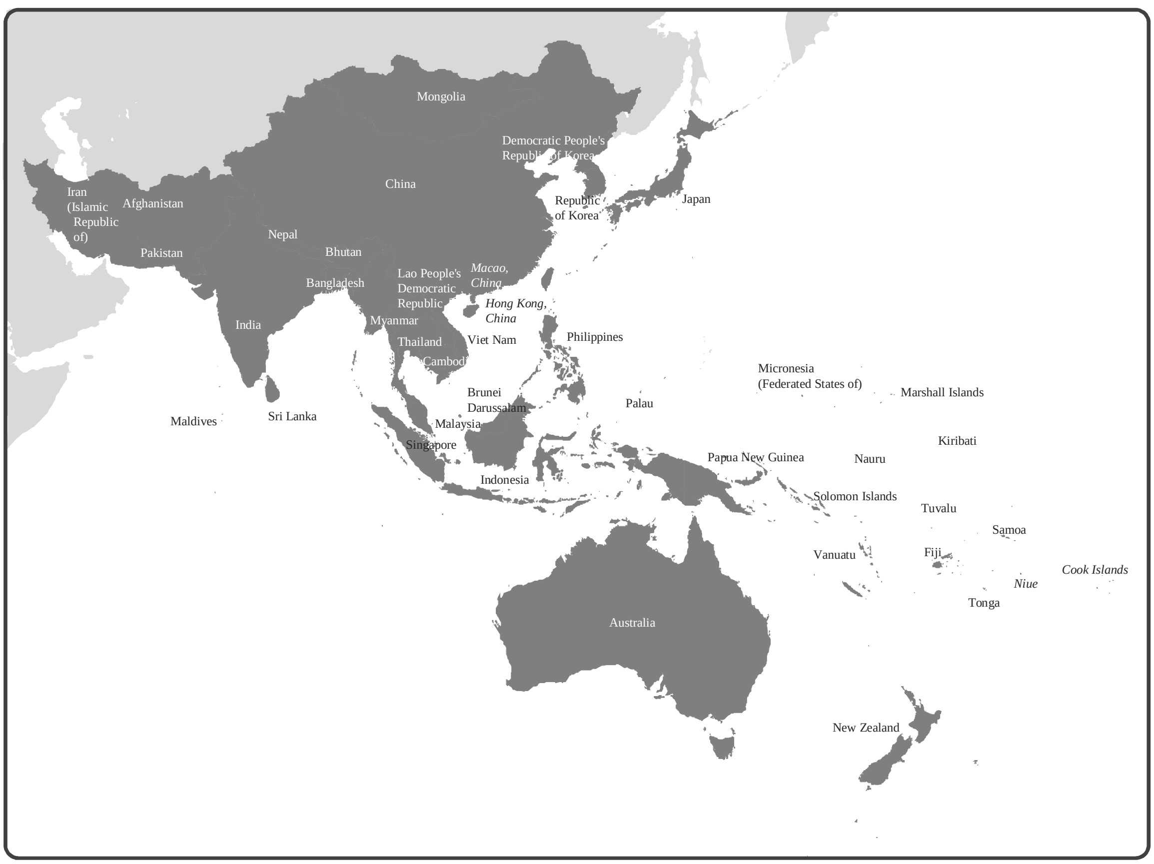
Asia-Pacific Telecommunity (APT) is the only intergovernmental organization specialized in the ICT field in Asia-Pacific region, established in 1979 by the joint initiatives of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and the International Telecommunication Union (ITU) with the objective of fostering the development of telecommunication services and information infrastructure throughout the region, particularly focus on developing areas.

Through its various programmes and activities focused on 5 Strategic Pillars as follow, the APT continues to support and assist its 38 members, 4 associate members and 136 affiliate members (as of April 2018) to realize the positive benefits of ICTs and cope with the challenges of rapidly evolving ICT environments.

For further information, please visit the APT website at https://www.apt.int.

Strategic Pillars of the APT (Strategic Plan of the APT for 2018-2020)

- **a. Connectivity**: Developing the digital Infrastructure;
- **b. Innovation**: Enabling conducive environments and harnessing the benefits of new technologies;
- **c. Trust**: Promoting security and resilience through ICT;
- **d. Capacity Building**: Promoting inclusiveness and enhancing expertise; and
- **e. Partnership**: Solidifying strategic cooperation with stakeholders.



38 Members and *4 Associate Members* of the APT

APT Publication of Research for

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Approaches to Fostering 21st-Century ICT Capabilities for Future Generations in APT Countries

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PREFACE

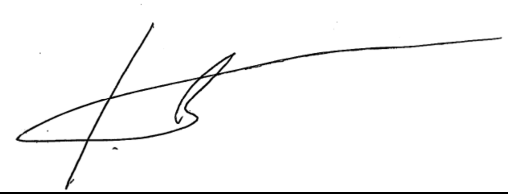
In the future, as information and communications technology evolve further and further, artificial intelligence and IoT will become even more widespread, and digital socialization will deepen. Under these circumstances, each country in the world faces the challenge of how to train personnel with 21st-century ICT capabilities (6C421C), who can actively engage in the coming digital society.

In recent years, it has become popular to provide basic computer science and programming learning opportunities for both elementary and preschool students in Japan. This phenomenon is not restricted to developed countries; as will be mentioned later, similar efforts also are observed in APT countries.

Through literature and field surveys conducted as a part of this publishing project, which was adopted by APT Publishing Program, we found that many countries are currently working with the enthusiasm to foster human resources for the future and to actively implement new initiatives and projects. Based on these movements, this book introduces the efforts and policies of each country, with some analysis of their characteristics, and points out three important factors in fostering 21st-century ICT capabilities: a vision for the next generation society, development of school curricula, and cooperation among government, industry, and academia. Our findings, however, are limited to the scope of the book's project, and there are likely various other approaches to 21st-century ICT capabilities that were not discussed hear.

This book itself is the result of collaboration between industry, government, and academia. Members of this project were gathered from the KDDI Foundation, the project's executing agency; FMMC, a not-for-profit organization; and the academic institutions of Shizuoka University and Chuo University. During the field survey, we visited four countries—Singapore, Malaysia, Thailand, and Myanmar—and conducted interviews, opinion exchange, and on-site surveys at 16 related sites, including government agencies, schools, and private organizations. As the project leader, I am deeply grateful to everyone who kindly supported and cooperated with our survey efforts.

Last but not least, I sincerely hope that the contents of this book will serve as a reference for interested parties in APT countries and will contribute to further information sharing and networking among APT countries.



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EXECUTIVE SUMMARY

The purpose of this publication project is to support the efforts of APT countries to develop 21st-century ICT capabilities required for the next generation by providing information on various countries' approaches and example good cases, with a focus on elementary and secondary education.

Today, the framework of practical work and social organization is changing from one of uniformity, which best suited mass production, to one of networking, collaboration, and partnership building. In the industrial field, realization of the Fourth Industrial Revolution, represented by IoT, big data, AI, robotics, and others, means it is necessary, as an important social issue, to foster creativity and information-using ability in next-generation human resources.

In light of these circumstances, an international organization established by educators worldwide, ATC21s, defines the general ability to survive in the global society of the future as "21st-century skills (ability to solve unresolved questions)"; these skills include critical thinking, problem-solving, communication, collaboration, information literacy, and so on. Given this, in this book we define "21st-century ICT capabilities" as a set of several capabilities, powered by use of ICT, that all people living in the 21st century should ideally be equipped with.

Various abilities and skills can be considered as elements of 21st-century ICT capabilities. Of those, this book considers six C's (Computational thinking, Coding, Creation, Communication, Collaboration, and Competition) to be particularly important. These six are abbreviated as "6C421C" (six C's for the 21st century).

This book consists of five chapters: an introduction, Chapters 1 to 3, and a conclusion. In the Introduction, we present the purpose of this book, the definition of 21st-century ICT capabilities, and the book's approach and composition.

In Chapter 1, we outline the vision for the next generation and associated measures to foster 21st-century ICT capabilities in Europe, the U.S., and the APT countries; we examine the characteristics of each country's approach using basic statistical data. Within the scope of the investigation, countries that are aggressively pursuing 21st-century ICT capabilities have formulated social and economic visions and strategies for the next generation. Despite differences in the economic and social situation of each country, these visions and strategies generally include three aspects: to strengthen competitiveness and innovation, to develop next-generation human resources capable of responding to globalization, and to foster next-generation citizens who will live in the future digital society.

In Chapter 2, we introduce the example cases and efforts made in Europe, the U.S., and the APT countries to improve school curriculum with respect to development of 21st-century ICT capabilities, and categorized them into three types: the CS compulsory independent subject type, the integrated STEM type, and the 21st-century skill type. In the CS compulsory independent subject type, the main objective is understanding of and skill acquisition in computer science (CS).

In the integrated STEM type, the main purpose is to improve numeric and scientific thinking ability. An integral part of the 21^{st}-century skill type is to nurture 21^{st}-century ICT capabilities and thereby foster citizens who can participate in the digital society. Additionally, aspects of each type involve improving problem-solving ability by utilizing IT and human resource development in the IT field.

In Chapter 3, we show cases from each country to introduce the role of industry-government-academia collaboration in nurturing 21^{st}-century ICT capabilities. To cultivate 21^{st}-century ICT capabilities (including CS and STEM subjects), it is necessary to improve learning materials, tools, and ICT environments (networks, computers, etc.), as well as to train teachers. Collaboration between industry, governments, and academia can expect a synergistic effect through the linking of each entity's respective strengths. Industries, including nonprofit organizations and companies, can develop learning tools, devices, and services that utilize the latest knowledge; standardize learning content, raise awareness through grassroots networks; and lobby to reform regulatory frameworks. Government agencies can lead the coordination among industry, government, and academia; conduct policy planning; develop legal and regulatory frameworks; and revise school curricula and deploy them nationwide. Finally, academic societies can ensure theoretical readiness of 21^{st}-century ICT capabilities, offer a place for teacher training, and promote cooperation among schools.

The final chapter provides a summary of the book's contents. Although this book does not cover all approaches to fostering 21^{st}-century ICT capabilities, as its content is based on the results of research concerning the U.S. and selected countries in Europe and the APT, it has significance in that it shows various approaches that have actually been introduced. Going forward, measures to foster the next generation must be promoted by strengthening information exchange and cooperative relations between and outside the APT countries. We, as contributors to this APT publishing project, sincerely hope that the content of this book will aid in this effort.

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National Institute of Education, Learning Science Laboratory, Singapore

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Infocomm Media Development Authority, Singapore

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National Strategy Unit, Ministry of Finance Malaysia, Malaysia

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Code Juniors, Malaysia

Ms. Jacqueline Lee [Business Dev. Manager]

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Saitama University

Nomura Tairo [Associate Professor, Faculty of Education]

Embassy of Japan in Thailand

Onga Hagime [First secretary]

Embassy of Japan in Malaysia

Masuhara Tomohiro [First secretary]

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1 Purpose of this book

The purpose of this publication project is to support the efforts of APT countries to develop 21st-century ICT capabilities required for the next generation by providing information on various countries' approaches and example good cases, with a focus on elementary and secondary education.

Today, the framework of practical work and social organization is changing from one of uniformity, which was suited for mass production, to one of networking, collaboration, and partnership building. In the industrial field, realization of the Fourth Industrial Revolution, represented by IoT, big data, AI, robotics, means it is necessary, as an important social issue, to foster creativity and information-using ability in next-generation human resources.

In light of these circumstances, an international organization established by educators worldwide, ATC21s, defines the general ability to survive in the global society of the future as "21st-century skill (ability to solve unresolved questions)"; these skills include critical thinking, problem-solving, communication, collaboration, information literacy, and so on. Along with this, governments are starting to shift from traditional education systems emphasizing knowledge to new systems that nurture and extend these 21st-century skills.

Based on the above, this book presents the concept of "21st-century ICT capabilities," and introduces noteworthy related activities and efforts in Europe, the U.S., and APT countries based on literature and on-site surveys. This book shows our findings by organizing elements and approaches that foster 21st-century ICT capabilities at the primary and secondary education levels.

2 What are 21st-century ICT capabilities? - Definition, efforts in developed countries, and necessity in APT countries

(1) Definition of "21st-century ICT capabilities"

In this book, we define "21st-century ICT capabilities" as a set of various abilities, powered by use of ICT, that all people living in the ICT-based society of the 21st century should ideally be equipped with.

Various abilities and skills can be considered elements of 21st-century ICT capabilities. Of particular importance are six C's: Computational thinking, Coding, Creation, Communication, Collaboration, and Competition, or "6C421C" (six C's for the 21st century).

To define the concept of the "21st-century type skill," the nonprofit organization P21 (Partnership for 21st Century Learning) presented the "Framework for 21st Century Learning" in 2008. The concept was also defined in 2012 by ATC21s (Assessment & Teaching of 21st Century Skills), a project focused on 21st-century type skills. ICT skills are an important component of the above framework and definitions.

For example, in P21's framework, the core knowledge and three skills learners must acquire are as follows (this indicates the significance of ICT skills in the framework):

- Content Knowledge and 21st-Century Themes
- Three Skills
    - Learning and Innovation Skills
    - Information, Media, and Technology Skills
    - Life and Career Skills

In this book, ICT skills in particular are recognized as essential for improving more fundamental abilities such as creativity, cooperativeness, and logic by utilizing information, media, and ICT technology. In recent years, developed countries have been actively promoting development of programming skills, including understanding of algorithms, in elementary and secondary education.

In light of these circumstances, "21st-century ICT capabilities" in this book refers to both ICT skills and programming skills themselves, as well as the capabilities thought to be acquired by utilizing a wide range of ICT skills. The elements of these capabilities include Computational Thinking, Coding (Programming), Creation, Communication, Collaboration, and Competition. Nurturing these 21st-century C's should build upon the traditional 3R's (reading, writing, and arithmetic). One feature of this book is its focus on measures in elementary and secondary education to foster 21st-century ICT capabilities.

(2) Measures to foster 21st-century ICT capabilities in developed countries

Since the early 2010s, developed countries have been actively developing 21st-century ICT capabilities. As a remarkable example, the U.K. made "computing" an independent and compulsory subject at primary and secondary schools in 2014. In addition to the introduction of computing as an independent and compulsory subject, there are several cases in which content related to 21st-century ICT capabilities is included in each subject and elective course. Because these efforts could serve as a reference for APT countries, this chapter introduces the leading initiatives and measures described in each chapter.

(3) Necessity of fostering 21st-century ICT capabilities in APT countries

Efforts to foster 21st-century ICT capabilities have been seen outside the developed countries as well. For example, Malaysia introduced "computational thinking" and "computer science" to the National Curriculum, which defines the learning contents for primary and secondary schools, in 2017. Behind such movements is the increasing importance of ICT in economy and society. Under these circumstances, there is growing recognition of the necessity of 21st-century ICT capabilities for the next generation, even in semi-developed and developing countries.

3 How to foster 21st-century ICT capabilities for the next generation in APT countries

(1) Nurture 21st-century ICT capabilities as basic elements of elementary and secondary education

Given recent wide-ranging application of Artificial Intelligence (AI) technologies and deployment of IoT (Internet of Things) products and services, ICT will undoubtedly be widely used in society in future. It is expected that ICT will be used not only in traditional Internet services, but also in a wide range of fields such as transportation, energy, administration, education, and the medical and agricultural fields.

In this sense, human resources with the ability to skillfully handle ICT and to creatively develop future society and industry are needed in a wide range of fields. Fostering 21st-century ICT capabilities in the next generation is an important effort with social significance not only for developed countries, but also for semi-developed and developing countries, which will promote the Fourth Industrial Revolution utilizing AI and IoT.

Various countries in the Asia-Pacific region participate in the APT, and their social, economic, and cultural backgrounds are diverse. There are also important differences regarding industrial structure, educational systems, and ICT fields.

Additionally, because 21st-century ICT capabilities are not a single ability but a set of various skills, knowledge, abilities, and attitudes, it is possible to implement them using diverse approaches. In such approaches, as efforts in various countries have grown more active since the early 2010s, the target age has been lowering. Traditionally, ICT ability has been treated as a specialized skill, mainly offered in subject courses of the higher education and university level. However, the increasing efforts of the 2010s target elementary and junior high students, as well as citizens for lifelong learning. This indicates that ICT ability is becoming a basic necessity that all people must acquire.

(2) Three common requirements for fostering 21st-century ICT capabilities

In some APT countries, efforts to foster 21st-century ICT capabilities have already been seen, but measures at the primary and secondary education levels are expected to increase in future. Therefore, we focus on measures to foster 21st-century ICT capabilities at the primary and secondary education levels, and conducted literature and field surveys to prepare this book. From these surveys, we found three common conditions considered beneficial to any country wishing to promote 21st-century ICT capabilities at the primary and secondary education level.

These conditions are as follows:

1. Formulation of policies for developing 21st-century ICT capabilities with a socioeconomic vision for the next-generation society.
2. Reform of the educational system at the national level with respect to 21st-century skills.
3. Enhancement of learning opportunities with bottom-up efforts through cooperation and networking between industry, government, and academia.

From the literature and on-site surveys, we found that several countries were promoting 21st-century ICT capabilities with a socioeconomic vision and strategies for nurturing the next generation, not only in Europe and the U.S. but also in APT countries. These visions and strategies serve as a foundation for developing legal systems and frameworks to promote concrete measures.

Additionally, the fact that vision and strategy are shared by society as a whole contributes to smooth cooperation between stakeholders. Twenty-first-century skills emphasize more creative and problem-solving skills and abilities. To that end, it is necessary to expand learning opportunities to include new skills and abilities, not only in school education but also in society as a whole. However, the use of ICT was generalized only in recent decades, and technological innovation is extremely rapid. Therefore, cooperation between private companies and nonprofit organizations, some of which may be supported by private companies to drive technological innovation and dissemination of ICT, is an important requirement for developing practical 21st-century ICT capabilities.

(3) Various approaches to realizing the three requirements for 21st-century ICT capabilities

There is no single approach to realizing the above three requirements, rather various methods and options according to the circumstances of each country. For example, it is desirable that the socioeconomic vision for the next generation (requirement 1) is consistent with the country's actual socioeconomic situation. In fact, unique socioeconomic visions have been formulated in Europe, the U.S., Japan, and APT countries according to their individual situations. In addition, it would be beneficial to clarify the image of the human resources of the next generation, and how to link the vision with 21st-century ICT capabilities according to each country's situation.

Likewise, various approaches are possible to nurture 21st-century ICT capabilities by implementing national education reform. In the case of challenges in strengthening mathematics and science subjects in the U.S., 21st-century ICT capabilities could also be nurtured as part of the solution. Additional options exist, such as the introduction of computer science courses in the U.K. It should be noted, however, that the resources (budget, personnel, experience, etc.) available for implementing ICT teaching materials, teacher training, and preparation of school ICT environments necessary for realizing educational reform differ from country to country. Where such resources are abundant, short-term nationwide introduction of independent subjects is possible; medium-term efforts are more desirable for countries with fewer resources.

Under these circumstances, noteworthy efforts are being made in various countries to expand learning opportunities regarding 21st-century ICT capabilities using a bottom-up approach through collaboration between industry, government, academia, and society. According to our surveys during this project, there are numerous examples of best practices and cases for expanding learning opportunities regarding 21st-century ICT capabilities through the activity of nonprofit organizations, some of which are supported by private enterprises eminent in the U.S.; through cooperation by universities, as in New Zealand, where a new learning material ("Unplugged") was developed; and through, for example, the report of the Royal Society, which advanced educational reform in the U.K. In addition, efforts to strengthen collaboration between industry, government, and academia led by governmental initiatives, as in Malaysia, are a highly effective approach. Through collaboration between industry, government, and academia, trial efforts are possible at preliminary stages before uniform introduction to all schools, as well as projects targeting talented students. We believe that such trials are useful in establishing measures to foster 21st-century ICT capabilities that are appropriate to the circumstances of each country.

4 Structure of this book

Based on this brief introduction, this book introduces examples of best practices and cases in each chapter according to the three requirements presented above. The composition of this book and the outline of each chapter are as follows.

Introduction - 21st-century ICT capabilities for the next generation

This chapter described the purpose of this book and the concept of 21st-century ICT capabilities. Based on efforts in developed countries to expand 21st-century ICT capabilities, this chapter pointed out the necessity of similar efforts in APT countries. In addition, we presented three common requirements for development of 21st-century ICT capabilities for the next generation of APT countries. In the following chapters, these three requirements will be discussed in detail.

Chapter 1 - Vision for the next generation and fostering 21st-century ICT capabilities

Chapter 1 discusses the approaches of the U.S. and several countries in Europe and the APT concerning *formulation of policies for developing 21st-century ICT capabilities with a socioeconomic vision for the next generation*. We additionally summarize the features of each country's efforts based on its economic and social development and improvement of school ICT environments, with reference to basic statistical data. Chapter 1 shows that with a vision for the next generation, policy formulation, construction of institutional frameworks, and various other measures can be developed smoothly.

Chapter 2 - Development of school curricula to foster 21st-century ICT capabilities

Chapter 2 introduces the approaches of the U.S. and the European and APT countries regarding *reform of the educational system at the national level with respect to 21st-century skills*. School curriculum reforms are classified into three types—the CS compulsory independent subject type, the integrated STEM type, and the 21st-century skill type—and the characteristics of each are summarized. In addition, Chapter 2 presents a combination of several measures for reform of educational systems, including a curriculum preparation for training "21st-century type skills," teaching material preparation, faculty support, and so on, according to the aims and situation of each country.

Chapter 3 - The role of industry-government-academia collaboration in fostering 21st-century ICT capabilities

Chapter 3 presents the best practices and approaches of the U.S. and countries in Europe and the APT countries concerning *enhancement of learning opportunities with bottom-up efforts through cooperation and networking between industry, government, and academia*. In Europe and the U.S., nonprofit organizations are quite active and contribute to expansion of learning opportunities regarding 21st-century ICT capabilities by developing and offering advanced learning tools and services, both nationally and globally. We also introduce the efforts of some APT countries to create new networks and collaboration between industry, government, academia, and stakeholders.

Conclusion - Fostering 21st-century ICT capabilities in the next generation in APT countries

To serve as a reference for APT countries in implementing measures related to 21st-century ICT capabilities, the final chapter summarizes the approaches and cases presented in Chapters 1 to 3, categorizes the next-generation visions and school curriculum development types, and briefly describes the characteristics of collaboration in each country between industry, government, and academia referred to in previous chapters.

The contents of this book are based on various publications and websites, information gathered during field research conducted in four southeast Asian countries (Singapore, Myanmar, Thailand, and Malaysia, May to June 2017), and information gathered through an independent research project of the FMMC (U.K. and Finland, September 2016).

Chapter 1 - Vision for the next generation and 21^{st}-century ICT capabilities

Introduction - Next-generation vision in the Fourth Industrial Revolution and development of 21^{st}-century ICT capabilities

In recent years, movements to expand computer science education (including ICT literacy and programming) in primary and secondary education are increasing in Western and Asian countries. Simultaneously, there is worldwide change in industrial structure due to the Fourth Industrial Revolution (improvement of the service/industry ratio in each country's GDP, improvement of productivity using ICT, etc.).

The Fourth Industrial Revolution has also caused a change in the consideration of human resources who can actively contribute to society. Efforts to foster 21^{st}-century skills at the primary and secondary education levels can be understood as a reaction to the emergence of a new vision for human resources. In addition to actions by government and educational institutions, efforts by private companies and nonprofit organizations are growing more active. The former contribute by expanding learning opportunities through planning related curricula and curriculum revisions, and the latter by offering hands-on programming and robotics opportunities as after-school activities.

As reasons increase for such society-wide efforts to foster next-generation ICT human resources at the primary and secondary education levels, national vision for the next-generation socioeconomic future and national strategy for realizing this vision are vital. In the era of mass production, economic policies planned by the government had some effectiveness. However, with the Fourth Industrial Revolution, not only are human resources and abilities to provide high-quality services and products utilizing ICT needed; society itself is also transforming.

Under these circumstances, formulating and sharing a next-generation socioeconomic vision and national strategy are a foundation for establishing the institutional development and policies that will lead to the new era. Additionally, if the vision and strategy for the next generation are shared, it will be easier to gain understanding and cooperation from stakeholders. In fact, in the U.S., European countries, and others, a vision and prospect for the next-generation socioeconomic future are shared among society, which aims to enjoy the benefits of the Fourth Industrial Revolution by responding to the social and economic changes it brings.

This chapter presents three cases from Europe and the U.S. and four cases from APT countries showing how 21st-century ICT capabilities are reflected in each country's next-generation socioeconomic vision. In addition, this chapter categorizes the vision and strategy of with reference to basic statistics such as the competitiveness of each country, the ICT environment of the school, and so on. Finally, policy requirements or institutional conditions are considered in terms of full development of 21st-century ICT capabilities.

1-1 Global economic competitiveness in Europe and the U.S. and fostering 21st-century ICT capabilities

(1) U.S.: Innovation strategy and measures to strengthen STEM education

The U.S. government has recognized that strengthening science, technology, engineering, and mathematics (STEM) ability is indispensable in maintaining and developing the environment for industrial competitiveness and innovation.

During the Obama administration, development of innovative educational technology and promotion of human resources development were included in a series of Strategies for American Innovation presented in 2009, 2011, and 2015. Additionally, computer science was positioned as a core learning subject in elementary, secondary, and higher education in the "Every Student Succeeds Act" (ESSA) that came into effect in December 2015. Under the Trump administration established in 2017, the President's memorandum of understanding in November 2017 stated that expansion of high-quality STEM education and computer science education would continue in 2018.

The background to such efforts is the issue that younger American generations' achievement in STEM remains lower than that of Europe and advanced Asian countries. In addition, given a lack of human resources capable of responding to jobs requiring advanced IT skills, nonprofit organizations such as Code.org and IT companies have begun actively providing programming learning opportunities.

(2) U.K.: Emphasis on computer science as a basis for international competitiveness

In the U.K., during the Cameron administration established in 2010, a direction was set to fully revise the National Curriculum (equivalent to Japan's educational guidelines), aiming to improve teacher quality and class level, introduce a world-class educational system, eliminate education gaps, and so on.

This educational reform was characterized by tight collaboration between industry, government, and academia to raise the standard of academic ability, which is the foundation of international competitiveness that supports economic growth. Notably, computer science became an independent and compulsory subject in primary and secondary schools as of 2014. At that time, the grassroots community Computing At School (CAS) played a leading role, and the Royal Society, a science academy, developed an academic and theoretical framework. The administration also supported a private project to disseminate programming skill, "U.K.'s Year of Code," which began in 2014.

In recent years, the range of CAS's work has expanded, and the Network of Excellence (NoE) was formed. The NoE cooperates with various organizations to build and provide a nationwide support system to meet local needs (see Section 3-2).

(3) Finland: Emphasis on entrepreneurial spirit and ICT skills in globalization

In Finland's educational system, public education is the standard. They reformed the educational system in the 2010s to maintain and strengthen high-quality education and nurture the next generation as citizens, rather than focus on national industrial competitiveness and innovation. In Finland, the principle of the educational policies is to make high-quality education accessible to all people equally.

Finland's national curriculum was revised in 2016. Prompting this revision, it was noted that the abilities required for society and future work had changed since globalization spread as far as the classroom in the early 2000s. Moreover, Finland values entrepreneurial spirit, creative and innovative thinking, risk taking, and the ability to plan and act to achieve goals.

The National Curriculum, which has been in operation since August 2016, is characterized by introduction of seven Transversal Competences. ICT skills are among these competences, and programming is included in related subjects such as mathematics. In Finland, ICT usage environments at schools have been improved, teacher quality is high, and PISA learning outcomes by the OECD are ranked at the top level.

1-2 Vision for next-generation society in APT countries and 21st-century ICT capabilities

(1) Japan: Industry competitiveness conference and compulsory programming education in elementary school

In Japan, IT literacy education was introduced in elementary and junior high schools in 2002, and “information,” a new compulsory subject, was introduced in high school in 2003. Additionally, since the mid-2000s the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Internal Affairs and Communications (MIC) have promoted human resource development in the IT field to acquire advanced skills at the higher education level.

A plan to make programming education compulsory in elementary school starting in 2020 was presented at the 26th Industrial Competitiveness Council of the Prime Minister’s Office, held in April 2016, thereby fostering young people who could lead the Fourth Industrial Revolution under the circumstances of declining birthrate and aging population. In 2017, prior to full implementation of the curriculum guidance for defining the basic standard for education scheduled in 2020, the Japanese government declared that industry and educational institutions would collaborate to promote full-scale introduction of programming education at school through the platform of nonprofit organizations, such as the newly established “Future Learning Consortium” and others. With these measures, Japan is working on both curriculum reform in public education and expansion of afterschool learning opportunities through collaboration between industry, government, and academia.

With respect to expanding afterschool learning opportunities, since 2016 MIC has been working on a project using cloud services to demonstrate low-cost and effective implementation methods for programming education, leader training methods, and so on.

(2) Singapore: ICT talent and human resources development toward “Smart Nation”

Singapore is a city state with a small geographical area and no resources. Therefore, adopting the position that globally connected economic development was its only chance of survival, the Singaporean government has driven industrial development. The Singaporean government led the securing of talented human resources of society as a development bureaucrat and systematically organized development related organizations The government also participated in this development, attracting companies and improving the country's business environment. Under these circumstances, the "Smart Nation" initiative was announced in November 2014, with the goals of making Singapore a seamless, smart state using technology and realizing a meaningful and fulfilling national life.

Singapore also works to train ICT human resources from an early stage. Its efforts are characterized by emphasis on discovering and fostering talented ICT personnel and cooperating with vocational education while utilizing learning opportunities outside the school. In Singapore, the activities of extracurricular "Infocomm Clubs" and the National Infocomm Competition provide opportunities for students interested in IT to learn and compete.

In August 2016, the "Skills Future Singapore" project was established under the umbrella of the Ministry of Education to develop people's skills, and this contributes to human resource development in the IT field. Additionally, the Infocomm Media Development Authority (IMDA) introduced the "Code @ SG" initiative in 2017 to provide computational thinking education to children and students at the basic education stage. IMDA also provides the "Code for Fun (CFF) Enrichment Program" for elementary school students, which offers various programming learning opportunities outside the school.

(3) Malaysia: Promotion of Malaysia Blue Ocean Strategy and ICT human resource development

Malaysia is advancing the "Malaysia National Development Strategy" (MyNDS) through the framework of the national economic and social development plan "Eleventh Malaysia Plan (2016-2020)." The strategy's objectives are growth of GDP, expansion of investment, development of financial markets, promotion of employment, improvement of living, social inclusion, and so on. To realize these goals, Prime Minister Najib has advocated a national growth strategy, "Malaysia Blue Ocean Strategy" (NBOS) and promotes change in the economy, government, and society.

In Malaysia, computational thinking became a compulsory subject in primary and secondary schools in January 2017. This is the first case in Asia to make these subjects compulsory (see Section 2-1, paragraph (2)). The aim is to balance two goals: fostering excellent digital human resources to drive economic development, and ensuring digital inclusion of all citizens.

Under NBOS, the National Strategic Unit (NSU), a unit of the Ministry of Finance, promotes the computing project "Coding @ Schools" for children and students through the entrepreneurship training organization "StartupMalaysia." "Tech Human Resources Development and Promotion of Innovation" is one pillar of MDEC (Malaysia Digital Economy Corporation), which operates under the Ministry of Communications and Multimedia. As part of this, they promote a project for young people to promote and develop digital skill, "#mydigitalmaker."

(4) Thailand: Vision for a digital society and promotion of integrated STEM education

Within the framework of the 12th National Economic and Social Development Plan (2016-2021), the Prayut administration promotes a strategy to increase the appeal of the economy as a production and control center within the ASEAN region and to improve international competitiveness by refining industrial structure and investing in human resource development and R&D. Specifically, Thailand implemented investment promotion and cluster policies. The latter aims to develop the high-tech industry by combining industry sectors and regions through various incentives.

In Thailand, STEM education at the K-12 level is actively backed by the Department of Education and the Institute for the Promotion of Teaching Science and Technology (IPST), which serves as the foundation for promoting science and technology education nationwide. Reacting to the economic growth and progress of industrialization among middle-income countries, Thailand has responded quickly to the trend of STEM education in the U.S., and has continued its introduction and implementation. IPST announced "Thailand STEM Five-Year Master Plan (2015-2019)" in 2015. The plan has two pillars: 1) STEM for education, and 2) STEM for development of human resources.

STEM education in Malaysia is characterized by its aim to integrate between and among subjects. To promote integrated STEM education, regional STEM education centers are in charge of dissemination activities at the regional level, working with each prefectural advanced education institution.

1-3 Socioeconomic conditions and direction for 21st-century ICT capability development

(1) Competitiveness of each country, ICT development status at schools, and academic achievement at age 15

As shown above, various efforts to nurture 21^{st}-century ICT capabilities are seen in both advanced and APT countries. The diversity of these efforts is explained by the differing socioeconomic situation of each country; this leads to differences in the placement of 21^{st}-century ICT capabilities in policy objectives.

Table 1-1 shows the proportion of the service industry in GDP and the Gini coefficient, centered on the competitiveness ranking of industries of IMD or created countries. In addition, the table shows the number of computers per student, the proportion of students who use computers at school, and the PISA math score from the OECD data.

Table 1-2 Basic statistical data on socioeconomic conditions, ICT environment, and PISA math score

Ranking	IMD competitiveness rankings (Digital Competitiveness) (2017), [WEF competitiveness rankings] (2017-2018)	Service industry as a percentage of GDP (2016, *2015)	Gini coefficient (year)	Number of students per computer (2012)	Percentage of students who use computers at school (2012)	PISA math score (2012)
#1	Hong Kong (7) [6]	92.7*	53.7 (2011)	2.2	83.8	561
#2	Switzerland (8) [1]	73.8*	29.5 (2014)	2.7	78.3	531
#3	**Singapore (1)** [3]	**73.8**	**45.8 (2016)**	**2.0**	**69.9**	**573**
#4	**United States (3)** [2]	**78.9***	**40.0 (2007)**	**1.8**	**-**	**481**
#5	Netherlands (6) [4]	-	30.3 (2015)	2.6	94.0	523
#6	Ireland (21) [24]	57.5	31.3 (2013)	2.6	63.5	501
#7	Denmark (5) [12]	75.0	28.8 (2015)	2.4	86.7	500
#8	Luxembourg (20) [19]	87.4	30.4 (2013)	2.2	-	490

#9	Sweden (2) [7]	72.7	24.9 (2013)	3.7	87.0	478
#10	U.A.E. (18) [17]	-	-	4.2	-	434
#11	Norway (10) [11]	65.8	26.8 (2010)	1.7	91.9	489
#12	Canada (9) [14]	-	32.1 (2005)	2.8	-	518
#13	Germany (17) [5]	68.9	27.0 (2006)	4.2	68.7	514
#14	Taiwan (12) [15]	-	33.6 (2014)	5.8	78.8	560
#15	**Finland (4)** [10]	**70.6**	**21.5 (2015)**	**3.1**	**89.0**	**519**
#16	New Zealand (14) [13]	-	36.2 (1997)	1.2	86.4	500
#17	Qatar (28) [24]	47.6	-	4.2	-	376
#18	China (31) [27]	51.6	46.5 (2016)	2.9	38.3	613
#19	**United Kingdom (11)** [8]	**80.2**	**32.4 (2012)**	**1.4**	-	**494**
#20	Iceland (23) [27]	71.0*	28.0 (2006)	4.1	81.9	493
#21	Australia (15) [21]	73.1	30.3 (2008)	0.9	93.7	504
#22	Israel (13) [16]	-	-	4.7	55.2	466
#23	Belgium (22) [20]	77.0	25.9 (2013)	2.8	65.3	515
#24	**Malaysia (24)** [23]	**55.7**	**46.2 (2009)**	**16.7**	**-**	**421**
#25	Austria (16) [18]	70.7	29.2 (2013)	2.9	81.4	506
#26	**Japan (27)** [9]	**70.0***	**37.9 (2011)**	**3.6**	**59.2**	**536**
#27	**Thailand (41)** [32]	**55.8**	**44.5 (2015)**	**3.1**	**-**	**427**

Source: Created by the author using data from IMD, OECD, etc.

(2) Characteristics of each country's approach from the perspective of basic statistical data

a. Singapore: Maintaining competitiveness and developing next-generation ICT talent

In Table 1, Singapore earned the highest competitiveness ranking, and ranked first in digital competitiveness among the countries covered in this chapter. However, the Gini coefficient is also high in Singapore, suggesting that economic disparities exist.

The country's initiatives regarding 21st-century ICT capability development can be understood as an approach with focus on talent discovery and development, as ICT personnel training is enriched with learning opportunities outside school and vocational education for ICT is emphasized[1].

b. U.S.: Bottom-up science and mathematics achievement in social disparity and educational system reform

In the U.S., underlying the country's emphasis on raising the level of achievement in STEM subjects, the OECD PISA score is low, whereas the IMD competitiveness ranking is high. In response, the U.S. strengthened computer science learning opportunities in public education through educational system reform. Because the U.S. is currently experiencing a shortage of IT talent, nonprofit organizations supported by IT companies and other entities provide a wide variety of programming learning programs to broaden the IT talent pool. (see Section 2-2 (1)).

c. Finland: Creating citizens with a high ability to respond to globalization

Table 1-1 shows that Finland's digital competitiveness is ranked fourth. Economic disparity is small, and basic math ability is high. Classrooms are well equipped with ICT, which students actively utilize. Additionally, Finland is conducting educational reforms focusing on 21st-century skills to create citizens who can respond to globalization. ICT skills are presented as cross-sectional abilities among 21st-century skills. Finland's reform measures aim to foster citizens with high ability, which can lead to social development in the 21st century.

d. U.K.: Strengthening international competitiveness and close collaboration between industry, government, and academia

The U.K.'s service industry occupies a large proportion of its industrial structure, as is typical among developed countries. Economic disparity is not as great as in the U.S. or Singapore, nor as low as in Finland. The assumed reason behind the U.K.'s introduction of "computing" as an independent compulsory subject in primary schools is that the country gave priority to improving academic achievement as the basis for strengthening international competitiveness. Close collaboration between industry, government, academia, and citizens has proceeded quickly and smoothly throughout the process from policy formulation to introduction of the new curriculum.

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[1] Recently, Singapore also promotes integrated type STEM education. See 2-2 (3).

e. Malaysia: Top-down next-generation human resources development aiming to enter developed countries

Malaysia is rapidly climbing the competitiveness rankings. The country promotes efficient and prompt socioeconomic development through various master plans, with the goal of becoming an advanced country. With respect to fostering 21st-century ICT capabilities, Malaysia actively expands computing learning opportunities at the primary level through measures implemented under the national growth strategy “Malaysia Blue Ocean Strategy” (NBOS), in which high-impact and low-cost measures have been carefully selected.

f. Japan: Fostering next-generation human resources in the face of declining birthrate and aging population

In Japan, the PISA math score is high and classrooms are well equipped with ICT environments, as the proportion of service industries in GDP is growing. However, the industrial competitiveness rank is declining, and economic disparities are expanding. Given the social trends of declining birthrate and aging population, the Japanese government initiated a new policy to make programming a compulsory learning item in elementary school as of 2020, thereby fostering younger generations who can lead the Fourth Industrial Revolution. In preparation for this 2020 introduction, the Japanese government is conducting demonstration experiments and building cooperation channels between industry, government, and academia.

g. Thailand: Emphasis on science and mathematics and improvement of legal framework

In Thailand, competitiveness is ranked right next to Japan. The country is currently developing its legal system based on its vision for the digital economic society, and it is expected that implementation will be promoted in the near future. School ICT environments are currently undergoing a process of improvement, but future implementation of various measures proposed around 2015 should be noted.

Conclusion - View of human resources for next-generation industries and society and 21st-century ICT capabilities

In this chapter, we briefly outlined vision for the next generation and measures related to 21st-century ICT capabilities in the West and APT countries, and examined each country's features using basic statistical data. Within the scope of the investigation for this chapter, countries that are aggressively pursuing 21st-century ICT capabilities have formulated social and economic visions and strategies for the next generation. Although these visions and strategies differ according to the economic and social circumstances of each country, they include the following three goals:

1. Fostering next-generation human resources to strengthen innovation and industry competitiveness
2. Fostering next-generation human resources capable of responding to globalization
3. Creating next-generation citizens who will live in a digital society

With respect to item 1, countries must cultivate human resources who can find solutions to real-world challenges using new ideas, not only future IT human resources who will engage in system and software development, but also human resources in the economy, in which the service industry is expanding.

Item 2 indicates that ICT skill has become indispensable for the next generation's ability to respond to globalization, as economic globalization and the ICT industry are progressing concurrently.

Item 3 is based on a broader view of 21st-century ICT capabilities. It focus on more general, higher human capabilities such as logical thinking and creativity, with a view to human resources who can communicate using ICT and participate in a digital society.

Although the focus placed on these three viewpoints varies in proportion, all are addressed to some extent in each country's measures. Therefore, it is important to consider these three perspectives when setting and sharing vision and direction among society as a whole, thus forming the foundation for a legal and policy framework for fostering next-generation human resources with 21st-century ICT capabilities.

Chapter 2 - Development of school curricula to foster 21^{st}-century ICT capabilities

Introduction - Three types of school curriculum revision to foster 21^{st}-century ICT capabilities

There two basic approaches to fostering and expanding 21^{st}-century ICT capabilities: revising school curricula and expanding learning opportunities outside schools. With respect to the former, it is sometimes difficult to introduce new learning content or items, partly because the total learning hours at schools are not flexible and partly because curriculum revision is a complex task. However, as the importance of ICT continues to rise, several countries have recently revised public school curricula to expand 21^{st}-century ICT capabilities.

Movements to reform public school curricula at the primary and secondary education levels has spread to the APT countries as well as Europe and the U.S., as mentioned in Chapter 1. However, various approaches and related measures to revise public school curricula are seen in each country.

This chapter focuses on efforts related to development of 21^{st}-century ICT capabilities, especially with respect to public school curriculum revision at the primary and secondary education levels. This book's surveys showed that revisions to educational curricula to foster 21^{st}-century ICT capabilities can be roughly classified into three types: 1) the computer science (CS) compulsory independent subject type, 2) the integrated STEM type, and 3) the 21^{st}-century skill type. From the observed cases of each country's curriculum revision, multiple approaches and even combinations of several approaches were seen. This indicates that various approaches can be employed when revising school curricula to foster 21^{st}-century ICT capabilities.

2-1 CS compulsory independent subject type: Emphasis on basic understanding of CS

One method used to revise school curricula to develop 21^{st}-century ICT capabilities is introduction of new independent compulsory subjects such as computer science. A trend in recent cases showed countries introducing CS (including related subjects) as an independent compulsory subject in primary school education.

Table 2-1 summarizes the introduction of ICT-related subjects or learning items at the primary and secondary level in each country. Data were retrieved from the "Survey Research Report on Programming Education in Other Countries" published by MEXT in 2015.

Table 2-1 ICT-related subjects/learning items in each country

Country	Name of Subject	Independent Subject/Learning Item	Elective/ Compulsory	Target (P: Primary, S: Secondary)
U.K.	Computing	Subject	Compulsory	P and S
Estonia	Informatics	Subject	Elective	P
France	Information Digital Science	Item	Elective	S
Germany	Informatics	Subject	Elective	S
Finland	-	Item	Compulsory	P and S
Italy	Informatics	Unknown	Elective	P and S
Sweden	Technology	Subject	Elective	S (and vocational education)
Hungary	Informatics	Subject	Compulsory/Elective	P (compulsory) and S (elective)
Portugal	EduScratch	Unknown	Unknown	P and S
Russia	Informatics and ICT	Item (P), Subject (S)	Compulsory	P and S
U.S. and California	-	At each school's discretion	-	-
Ontario, Canada	Computer Studies	Item (P), Subject (S)	Elective	S
Argentina[*2]	Computing/Programming	Subject	Elective	S (and vocational education)
Korea	Jikka[*3] (P); Technology and Home Economics, Information (S)	Item	Compulsory/Elective	P (compulsory) and S (elective)
Singapore	Computer Applications	Subject[*1]	Elective	S
Shanghai, China	Information Science and Technology	Subject	Compulsory	P (compulsory) and S (elective)
Hong Kong	ICT (including programming)	Subject (General Skills)	Compulsory	S
Taiwan	Information	Subject	Elective	P and S
India	ICT, Computer Science	Item	Elective	P and S
Israel	Computer Science	Subject	Compulsory	S (high school on)

			(partial)	
Australia	Digital Technologies	Subject	Compulsory/Elective	P (compulsory) and S (selective)
New Zealand	Digital Technologies	Subject	Elective	S
South Africa	Information Technology	Subject	Elective	S
Japan	-	Item	Compulsory/Elective	P and S

[*1] ICT is included as one of seven basic abilities (core competencies).

[*2] Compulsory in standard school: technology course.

[*3] Technology and home economics subject.

Source: MEXT (2015), "Survey Research Report on Programming Education in Other Countries."

As shown in Table 2-1, CS subjects and ICT-related subjects are introduced in a relatively large number of countries, but few countries require them as compulsory independent subjects, as in the U.K. and Australia. As of 2014, the U.K. introduced "Computing" as a compulsory independent subject in schools to implement computer and science education for younger generations. In Australia, the "Digital Technology" subject was introduced in primary schools in 2017 (2016 in some schools to prepare for full-scale introduction). This section provides a brief overview of the background and characteristics of both these countries.

(1) U.K.: Primary and secondary school subject "Computing"

The Cameron administration in the U.K. revised the National Curriculum and made Computer Science a compulsory learning subject in the late 2000s, under pressure from industry and academia, which felt a sense of crisis over the content of information education in the U.K.. This revision introduced a new independent subject, "Computing," s compulsory education for 5- to 15-year-old students, replacing the previous "ICT (Information and Communications Technology)" subject.

The learning content of the new subject is based on a report entitled "Shut down or restart? The way forward for computing in UK schools," published by the Royal Society in 2012[2]. In this report, the Royal Society noted the limitations of the previous ICT subject, which dealt only with basic digital literacy such as using word processing and

[2] https://royalsociety.org/topics-policy/projects/computing-in-schools/report/
https://royalsociety.org/~/media/education/computing-in-schools/2012-01-12-computing-in-schools.pdf

database software, and it recommended the following:

1. Revision and redefinition of the term “ICT” and its leaning items
2. Training of teachers responsible for computing subjects and setting targets for the number of teachers
3. Improvement of infrastructure and teaching materials in schools
4. Promotion of introducing computing subjects in schools
5. Development of computing educational qualifications and construction of related institutional frameworks

For their first recommendation, they suggested including digital literacy, information technology, and computer science to the “Computing” subject as necessary learning items in U.K. information education. It is notable that the report comprehensively organized necessary measures for introducing the new subject in the first and forth items above, and suggested the second and fifth items, improvement of teacher quality and school ICT environments, in combination with other items. When implementing the new subject into the National Curriculum, Close collaboration and networking between industry, government, and academia supported the nationwide introduction and implementation of the new subject into the National Curriculum, including support for teachers and school ICT environments (see Section 3-2).

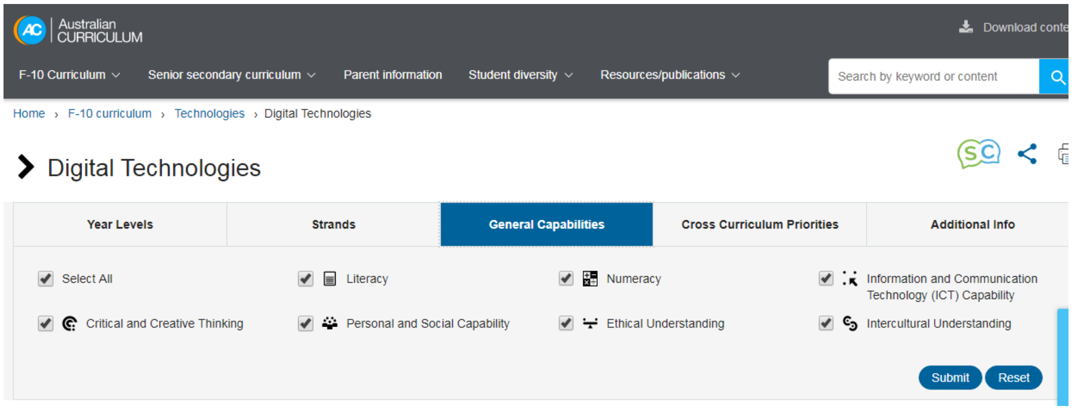
(2) Australia: Primary and secondary school subject "Digital Technologies"

In Australia, although educational content varies from state to state, a unified nationwide curriculum has been implemented based on the “National Education Guidelines” formulated in the later 1980s. However, because each state has authority over its educational measures, implementation of the National Curriculum varies from state to state.

The current nationwide unified curriculum was approved in September 2015 and has been implemented in each state sequentially since 2016. This revision made the independent subjects “Design and Technologies” and “Digital Technologies” compulsory in primary and secondary education. The country’s curriculum is characterized by its recognition of ICT ability as one of the general abilities in the National Curriculum developed and formulated at the federal level, and by its introduction of “Digital Technology” as a subject to cultivate ICT ability (see Section

2-3 (3)).

Figure 2-1 ICT capability as a general ability, and Digital Technologies as a subject



Source: Australian Curriculum[3].

(3) Malaysia: Gradual approach to introduction of "Computer Science"

Malaysia has adopted a gradual approach considering the developmental stage of students in its curriculum development to foster 21st-century ICT capabilities, which places emphasis on computational thinking.

In Malaysia, learning items including "Computational Thinking" and "Computer Science" were introduced to the Revised Standard Curriculum for Primary Schools (KSSR) for primary education as of January 2017. These learning items were implemented into primary education by weaving them into all subjects, rather than establishing new subjects. However, Malaysia introduced "Computer Science" as an independent subject for grade 1 of secondary education in 2017, and will introduce it for grade 4 in 2018.

To prepare for introduction of the new curriculum, over 17,000 teachers were trained from 2016 to September 2017 under the initiative of the Ministry of Education. The curriculum has been introduced to over 10,000 primary schools nationwide, accounting for 1.2 million primary school students. The curriculum was developed by MDEC with reference to "Computing at School" in the U.K. (see Section 3-2) and CSTA in the U.S. (see Section 2-2 (1)).

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3 https://www.australiancurriculum.edu.au/f-10-curriculum/technologies/digital-technologies/

2-2 Integrated STEM type: Development of practical and applied STEM learning

(1) U.S.: Strengthening STEM education and promoting computer science for all

In the U.S., there have been two approaches to improving STEM achievement level and opportunities to learn computer science. One is the top-down approach taken by the presidential office, and the other is the bottom-up approach taken by individual states and NGOs.

A unified national curriculum has not been formulated in the U.S., and curricula thus differ according to school. However, many states, including Arkansas and Virginia, have made computer science and information literacy compulsory in grades K-8 (elementary/secondary level).

To strengthen STEM education, the Obama administration launched the nationwide “Educate to Innovate” campaign in November 2009[4]. Measures introduced by this campaign have supported young people in collaboration with science- and technology-related major companies, foundations, nonprofit organizations, and academia, aiming to strengthen STEM education and raise achievement from mid-level to upper-level in the next ten years. In addition, the Obama administration established emphasis on STEM education, utilization of technologies, and utilization of non-traditional education methods when in an amendment to the Every Student Succeeds Act (ESSA) in December 2015.

The “Computer Science for All” initiative was announced in January 2016. This initiative noted that only an assumed one-fourth of K-12 schools taught computer science, including programming and coding, and that only 28 states accepted computer science subjects for credit to graduate high school. Given this, the initiative promised to fund expansion of computer science education and teacher training for K-12 education.

The Trump administration has also placed emphasis on STEM and computer science education, with President Trump ordering in his September 2017 Presidential Memorandum to the Department of Education to strengthen both subjects.

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4 https://obamawhitehouse.archives.gov/the-press-office/president-obama-launches-educate-innovate-campaign-excellence-science-technology-en

Other efforts by individual states and nonprofit organizations are also underway to standardize computer science education. For example, the state of California has been developing a standard for computer science education since 2017. The Computer Science Teachers Association (CSTA) revised its CSTA K-12 Computer Science Standards in 2011 and 2017, presenting standards for learning content[5], and has contributed to improving both quality and quantity of computer science education in schools.

(2) Thailand: Promotion of integrated STEM education and nationwide deployment

Like the U.S., Thailand has also promoted strengthening of STEM education. Thailand regards science and mathematics education as important for the country. In particular, Thailand is undertaking expansion of integrated STEM education, intending for the integration level to increase from “disciplinary” to “multi-disciplinary,” “interdisciplinary,” and finally “transdisciplinary.” At the transdisciplinary stage, students will be able to handle real-world challenges by utilizing knowledge of multiple subjects. In this way, Thailand’s approach sets the goal for students to acquire skills leading to critical thinking and innovation based on STEM knowledge.

This approach is one measure implemented to realize Thailand’s vision of increased international competitiveness, as human resources with high-level STEM abilities could contribute to enhancing Thailand’s economic capabilities. Thus, the National STEM Education Center, the core of 13 Regional STEM Education Centers, works to expand integrated STEM education. Advanced higher education schools from each prefecture are designated Regional STEM Education Centers, and these collaborate with STEM education network schools in each region. Schools serving as Regional STEM Education Centers prepare classrooms, participate in training courses, develop course materials, and share information on STEM education.

(3) Singapore: STEM applied learning program introduced at the junior high school level

Singapore has historically engaged in human resource development eagerly. The country has several programs and initiatives related to STEM education and human

[5] https://www.csteachers.org/page/standards
http://c.ymcdn.com/sites/www.csteachers.org/resource/resmgr/Docs/Standards/CSTA_K-12_CSS.pdf

resource development in the computer science and IT fields. Now, Singapore is shifting focus from elite or talent-oriented education, which placed emphasis on examinations and scores, to a more inclusive, practical, and substantial learning approach targeting all students.

As part of this effort, the Ministry of Education announced its plan to expand the STEM Applied Learning Program (STEM APL) in 2014. At that time, the Ministry set a target to increase the number of junior high schools offering STEM APL from 42 schools in 2014 to 124 schools by 2017.

Additionally, a new institution, STEM Inc., was established at the Science Center under supervision of the Ministry of Education. Both work together to support implementation of STEM APL in schools. Examples of such support include development of teachers in charge of STEM APL, co-development of STEM lessons, and joint implementation of lessons. Students who take STEM APL courses learn reasoning, problem-solving, scientific exploration, programming, and other skills. The courses place emphasis on practicality, and do not conduct tests.

2-3 The 21^{st}-century skill type: Ability to utilize ICT as a general capability

Some advanced countries, such as Finland, Japan, Australia, and others, introduced the concept of 21^{st}-century skills and identified several general abilities that cross subjects. In these countries, ICT-related skills and abilities are considered important components of general/cross-subject abilities. In other words, 21^{st}-century ICT capabilities are included in 21^{st}-century skills. In the case of Australia, several 21^{st}-century skills were specified, ICT ability among them. Australia's approach characteristically establishes independent subjects corresponding to ICT ability.

(1) Finland: Ability to utilize ICT as a cross-sectional ability

In Finland, ICT capability is recognized as one of seven cross-sectional abilities. Those seven are as follows:

- Thinking and learning to learn
- Taking care of oneself and others, managing daily activities, safety
- Cultural competence, interaction, and expression

- Multi-literacy
- ICT competence
- Work life competence and entrepreneurship
- Participation and influence, sustainable future building

These cross-sectional abilities are regarded as basic elements required for citizens and cultured human beings.

Among these abilities, ICT ability is regarded as both an aspect of multilingual skills and a learning tool. The four major learning areas of ICT ability are the following:

- Understand the principles of ICT usage, operation, and key concepts, and acquire practical ICT abilities.
- Use ICT responsibly, safely, and ergonomically.
- Use ICT for information management, explanation, and creative work.
- Use ICT for interactive networking.

(2) Japan: Ability to utilize ICT as a cross-sectional ability

The Japanese government showed the way to concretize the philosophy of "fostering zest to live" for the prospective society of 2030. "Zest to live" means the energy to live well and survive in the coming future society, which will be dynamically changing, by pursuing balanced development of well-cultivated academic capabilities, a sound and warm heart, and a healthy body.

When presenting this vision, the government referred to linguistic ability, information utilization (including ability to use ICT), and troubleshooting and problem-solving as abilities and skills necessary to handle modern issues. These correspond to 21^{st}-century skills. Additionally, ability to utilize information is mentioned as a cross-subject ability. The government announced that during the transition period starting in 2018 to the next course of study guidelines, programming would be included in the learning items of each subject step by step from elementary school on.

In the next course of study guidelines, which were published in March 2017 and are to be fully implemented in April 2020, learning content on information utilization ability and ICT utilization are shown in the course of comprehensive learning in primary and secondary school. Programming learning is included in mathematics, science, and other courses in elementary school, and in technology subjects in secondary school.

Additionally, since 2017 MIC has been implementing projects to promote and disseminate programming education nationwide utilizing cloud services.

(3) Australia: Ability to utilize ICT as a general ability of the 21st century

In Australia, the following seven general abilities are indicated for 21st-century education. Learning items and content are organized under these seven general abilities.

- Literacy
- Numeracy
- Information and communication technology (ICT) capability
- Critical and creative thinking
- Personal and social capability
- Ethical understanding
- Intercultural understanding

Multiple necessary elements of each respective ability are described. Further, learning contents for each element are organized. The required elements related to ICT ability are as follows:

- Applying social and ethical protocols and practices in using ICT (e.g., recognition of intellectual property and security assessment)
- Investigating with ICT
- Creating with ICT
- Communicating with ICT
- Managing and operating ICT

Furthermore, examples of learning elements are categorized to show how they should be learned, in what grade, and in which subject.

Conclusion - Fostering 21st-century ICT capabilities by improving school curricula

This chapter introduced approaches taken and outlined efforts to develop school curricula in each country to nurture 21st-century ICT capabilities, classifying the approaches into three types: the CS compulsory independent subject type, the integrated STEM type, and the 21st-century skill type.

Table 2-2 summarizes the skills and abilities emphasized by each approach to develop 21st-century ICT capabilities. In the U.K. and Australia, where independent courses on comprehensive subjects became compulsory nationwide, math and science achievement levels were relatively high. Emphasis in these countries was placed on expanding understanding of and improving skill in computer science. In Malaysia, computational thinking was introduced in primary education and independent courses on computer science in secondary education.

In contrast, the U.S. and Thailand promote integrated STEM type education intended to raise academic ability in math- and science-related subjects in particular. The U.S. is promoting expansion of computer science learning opportunities, but because the curriculum differs at the discretion of each state and each school, computer science subjects have not been introduced as compulsory courses at the national level. In Singapore, focus is on application and practical learning of STEM at the junior high school level.

Finally, Finland, Japan, and Australia are shifting to a framework involving learning of 21st-century skills. These countries aim to nurture citizens as members of a digital society with specific problem-solving and information use skills, and academic achievement in science and mathematics is high.

Furthermore, Australia has combined multiple approaches. These examples and cases show that various approaches are possible to foster 21st-century ICT skills through development and revision of school curriculum, based on the educational system and goals of each country.

Table 2-2 Three approaches to fostering 21st-century ICT capabilities by improving school curricula

	CS compulsory independent subject type	Integrated STEM type	21st-century skill type
CS understanding and skill acquisition	**X**		

Problem-solving ability using IT	x	x	x
Numeric and scientific thinking	x	**X**	
Human resource development for IT field	x	x	x
Information utilization capabilities and creativity		x	x
Participation in digital society			**X**

A common feature among the three approaches is that they foster ICT abilities necessary for life in the 21st century according to students' developmental level.

Additionally, in countries such as Singapore and the U.S., efforts to foster 21st-century ICT abilities are actively implemented outside the school curriculum. Fostering 21st-century ICT capabilities can thus be approached from the perspective of expanding learning opportunities outside the school as well.

Based on the above, Chapter 3 will discuss the role of cooperation between industry, government, and academia in fostering 21st-century ICT capabilities. Chapter 3 will examine two roles of this cooperation; expanding learning opportunities outside the school and improving the effectiveness of school curricula.

Chapter 3 - The role of industry-government-academia collaboration in fostering 21st-century ICT capabilities

Introduction - The role of collaboration and networking in developing 21st-century ICT capabilities

In Chapter 2, we introduced three approaches based on improving school curriculum. In any of these approaches, the following environmental improvements are indispensable when tackling 21st-century ICT capabilities:

- Training teachers to foster 21st-century ICT capabilities (including CS and STEM subjects)
- Developing learning materials and tools suitable for fostering 21st-century ICT capabilities
- Improving ICT environments (networks, computers, etc.) necessary for fostering 21st-century ICT capabilities

However, because fostering 21st-century ICT capabilities is a relatively new phenomenon, practical knowledge has not been sufficiently accumulated in governments and schools to develop the above elements, even from a global perspective. Under these circumstances, the activities of nonprofit organizations and collaboration and networking between industry, government, and academia have greatly contributed to the expansion and improvement. Such collaboration and networking has two aspects: expanding opportunities to acquire the 21st-century ICT capabilities outside the school, and developing schools' educational and learning environments for 21st-century ICT capabilities.

Therefore, this chapter will focus on the role of collaboration and networking in developing 21st-century ICT capabilities, and will introduce the following:

- Cases in Europe and the U.S. to expand learning opportunities and improve quality
- A case in the U.K. to introduce nationwide compulsory independent CS subjects
- Cases in APT countries using various approaches and methods

3-1 Global expansion of various initiatives by nonprofit organizations and IT companies

Various nonprofit organizations and IT/media-related companies engage in projects and initiatives to foster 21st-century skills and 21st-century ICT capabilities. Although this section does not cover all such initiatives and efforts, we focus on efforts that have been expanded globally based on research results.

(1) U.S.: Nonprofit organization P21 (Partnership for 21st Century Learning)

As mentioned in the Introduction, P21 works on concept arrangement and promotion of 21st-century skills. This nonprofit organization was established in 2002 by the initiative of the U.S. Department of Education and IT companies/nonprofit organizations[6]. P21 provides online information and materials on 21st-century skills for educators, policymakers, parents/communities, and project managers, and organizes a framework for "21st-century skills." The organization also publishes research results and conducts awareness-raising activities.

(2) U.S.: Nonprofit organization Code.org

Code.org is an organization founded in January 2013 with the aim of providing everyone with opportunities to learn computer science. The organization pursues the following goals to respond to a shortage of graduates with computer science degrees (just 2% among all science fields), citing that only an estimated 400 thousand undergraduate students major in computer science annually, while computer-related employment is estimated to expand to 1.4 million by 2020[7].

- Improve diversity in CS (computer science)
- Inspire students
- Create fantastic courses
- Reach classrooms
- Prep new CS teachers
- Change school district curricula

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6 http://www.p21.org/about-us/our-history
Funding organizations included AOL Time Warner Foundation, Apple, Cable in the Classroom, Cisco Systems, Dell Computer Corporation, Microsoft Corporation, the National Education Association, and SAP.

7 https://code.org/about

- Set up policies to support CS
- Go global

Cod.org provides courses free of charge and offers well-designed learning materials that are fun and easy to grasp even for elementary students. In addition, Code.org offers courses globally, and 15 million people from 180 countries participated in the organization's "Hour of Code" event in December 2014.

Code.org is supported by leading IT companies including Ballmer Family Giving, Facebook, Google, Infosys Foundation USA, Microsoft, and Omidyar Network, which have collectively donated more than $3 million; other donors include include Amazon, Bill Gates, Verizon, and Salesforce, who have donated over $1 million.

In the U.S., many nonprofit organizations, such as Code Academy and Kahn Academy, offer online programming courses in addition to Code.org.

(3) U.S.: Development of new programming learning tools by IT companies

a. Google: Blockly, Scratch Blocks

Google has developed and offered tools for learning programming. For example, beginning in 2012, Blockly was offered as part of Google Education, a cloud service geared toward educational institutions. This tool provides a web-based visual programming environment, operated using the mouse, that is sophisticated enough to embed in actual web services and to work with other programming languages such as JavaScript and Python. Google also launched Blockly Games, which provide learning in game format, in 2014.

In May 2016, Google announced a collaboration with MIT's Scratch team to develop Scratch Blocks, a next-generation visual programming tool based on the Blockly technology. As an aside, several programming learning tools were developed by universities relatively early on. Scratch, which has been in development at the MIT Media Lab since 2006, is a typical example. Scratch is a blocking programming tool; its previous version 1.4 required installation on a PC, but the version 2.0 made it usable in web browsers. The tool was developed with support from the National Science Foundation (NSF), Scratch Foundation, Google, LEGO Foundation, Intel, Cartoon

Network, Lemann Foundation, and MacArthur Foundation. It is used for a wide range of ages, though it is designed for children 8 to 16 years old. Scratch Jr, a free application for iPad and Android targeting 5- to 7-year-olds, was released in July 2014.

b. Apple: Swift Playgrounds

Apple also works to develop programming learning tools. In June 2016 at WWDC (Worldwide Developer Conference), an annual conference for developers, they announced Swift Playgrounds, a learning tool for the programming language Swift, which can be used to develop apps for iOS. This tool was designed to teach people the basics and outlines of Swift before proceeding to more specialized and advanced learning, and became available in the Apple Store in September 2016. According to Apple's press release, more than 100 schools worldwide decided to add Swift Playgrounds to their curriculum as of the 2016 fall semester. Swift was originally released at WWDC in 2014 as a new programming language for application development, and was open-sourced in December 2015. In addition to these efforts, Apple offers workshops called Apple Camp annually in July and August for children 8 to 12 years old.

c. Microsoft: "Minecraft: Education Edition"

Most noteworthy among Microsoft's efforts was its acquisition of Mojang for $2.5 billion in 2014. Mojang, a Swedish indie PC game developer, was famous for developing Minecraft, a world hit game at the time. Minecraft allows players to place blocks freely in the air or on the ground of a virtual world. An educational version, MinecraftEdu, was available prior to the company's acquisition by Microsoft. Microsoft announced in January 2016 that they would offer "Minecraft: Education Edition" for educational institutions considering offering programming education. A beta version was rolled out in June 2016, and the full version released in November of the same year. More than 50,000 students and teachers used the beta version, contributing to its improvement. Functions added to the beta version were as follows:

- Sharing among up to 30 people without setting up a server
- Restriction of student usage range and management of learning progress
- "Guidance" and "blackboard" functions for guiding students
- Ability to take photos freely within Minecraft's virtual space

The improved edition is available in 23 languages as of August 2017[8]. The per-person usage fee is $5 per year[9].

(4) New Zealand: "CS Unplugged" learning materials for young age groups

"CS Unplugged" is a teaching material for computer science targeting young students, developed through a project of the computer science education research group of Canterbury University, New Zealand. Not only Google but also researchers from New Zealand, the U.S., the U.K., Canada, France, Japan, Sweden, China, and other countries contributed to its development.

The purpose of the "CS Unplugged" project is to provide educational computer science materials at home and in classrooms for young age groups, including elementary school students, in a universally accessible form for developed or developing countries. Its development principles are as follows:

- It does not require a computer
- It is real computer science
- Users learn through activities.
- It is fun
- No special equipment is required
- Creation of various revised versions is recommended
- It is intended for everyone
- It is cooperative
- Individual learning activities are independent
- It is robust

Based on these principles, various activities to learn computer science have been developed and summarized in a book (PDF form) that has been continually updated. "CS Unplugged" is available in 25 languages and includes videos related to its learning items.

8 https://education.minecraft.net/support/knowledge-base/language-availability/
9 https://education.minecraft.net/support/knowledge-base/purchasing-minecraft-education-edition/

(5) Finland: "Rails Girls" workshop and learning picture book Hello Ruby

In Helsinki, Finland, Linda Liukas and Karri Saarinen held "Rails Girls," a two-day free workshop for women using Ruby on Rails as a development framework for web applications. More than 100 women attended the workshop in November 2010. Afterward, the activity was deployed worldwide. Materials for event organization and the tutorial "Rails Girls Guide" are offered in 11 languages[10].

Liukas also worked with Juhani Mykkänen, with support from the Finnish Development Fund (Sitra), to create "Koodi 2016," a guideline for teachers unfamiliar with programming, in 2014. The same year, she published a picture book to teach children programming, *Hello Ruby*, which was funded through Kickstarter.

3-2 Role of industry-government-academia collaboration and networking in nationwide introduction of independent CS courses in the U.K.

(1) Role of grassroots activity network CAS

As described in Chapter 2, the U.K. introduced the compulsory independent CS subject "Computing" to expand 21st-century ICT capabilities. This was accomplished through close collaboration between industry, government, and academia. In particular, Computing at School (CAS), a grassroots community that advocates for change in information subjects in traditional school education, played a lead role. The Royal Society, a renowned academy of sciences that supported theoretical framework development, also urged the IT industry and administration to introduce "Computing" in a short time frame.

(2) National curriculum amendment driven by industry-government-academia collaboration

When the Ministry of Education began to develop a new version of its study programs (guidelines for learning instruction) in the latter half of 2012, the revision process for ICT-related subjects was quite different from usual. After a year of holding meetings and drafting an informal policy paper, the Ministry of Education, BCS, and CAS had fostered a trusting relationship. Based on this, the Ministry of Education invited a wide

[10] https://guides.railsgirls.com/

range of stakeholders from BCS and the Royal Society to compile the study program.

As a result, revision of ICT-related subjects for the national curriculum was completed within a fairly short period of time. The draft version was completed in November 2012, just two months after the initial invitation to stakeholders in September 2012, two work parties, and consultation by the CAS community. Subsequently, the Ministry of Education made minor modifications to the draft, and public consultation was conducted in February 2013. The subject “Computing” in the formal national curriculum was officially announced in September 2014.

(3) “Network of Excellence” (NoE) supporting teachers in the region

The support network for teachers of “Computing” in schools, begun by CAS, has been expanding every year in both quality and quantity. This network is called the “Network of Excellence” (NoE)[11]. Various institutions work with the NoE to fulfill local needs. Specifically, the nationwide network includes CAS Regional Centers, CAS Master Teachers, CAS Hubs, universities affiliated with CAS as CAS University Partners, and advanced schools recognized by CAS as CAS Lead Schools.

(4) Collaborative work by telecommunications carriers and media companies

a. Contributions by BT to support CAS: Barefoot project

BT, a major U.K. telecommunications carrier, has long contributed to building a technology and literacy culture in the U.K. as a responsible ICT company for next-generation ICT society. As part of that, they announced their cooperation with the educational support project Barefoot in July 2014, shortly before the September introduction of “Computing” in the national curriculum. The Barefoot project was designed to support elementary school teachers and conducted by BCS starting in 2014, funded by the Ministry of Education and supported by various companies including BT and Raspberry Pi.

BT has also played a role in fostering technology literacy in younger generations and teachers as a provider and improver of “Computing” facilities and environments, making the subject universally accessible in the context of technological innovations

[11] https://www.computingatschool.org.uk/noe

such as IoT, AI, big data, and so on. This contribution by BT is a good example of the beneficial effects of close cooperation between government, schools, and related stakeholders on increasing the international competitiveness of the U.K. in the future digital society.

b. Contributions by public service broadcaster BBC

The BBC is an international public broadcasting company offering services in the U.K. and globally. It is famous for pioneering new services, including the world's first launch of terrestrial digital broadcasting and on-demand service, "BBC iPlayer," to promote digitization of broadcasting services.

In recent years, the BBC has promoted a project called "Make it Digital" with the aim of fostering the digital skills of young people who will be responsible for the next generation. The BBC's contributions characteristically focus on digital creativity and commitment to supporting enhancement of young people's digital skills.

As part of these efforts, the BBC developed an easily portable pocket-sized (4 x 5 cm) computer, the "micro:bit," for the purpose of mastering programming. In March 2016, began distributing "micro:bit" free of charge to all domestic secondary school first-years (11 years old), a total of approximately 1 million students.

Furthermore, in October 2016 the BBC established the micro:bit Educational Foundation to promote computing education, expanding upon their micro:bit distribution activity as its usage had spread nationally among first-years in secondary schools.

3-3 Efforts to foster 21st-century ICT capabilities through collaboration between industry, government, and academia in APT countries

(1) Japan: Regional collaboration by industry, government, and academia, and social participation-type 21st-century ICT capability development

In Japan, "Collaboration for Future Learning Consortium," a collaborative organization involving industry, government, and academia, was established in March 2017 in response to the planned introduction of compulsory programming education in 2020.

The consortium aims to connect private companies and schools and to constantly provide and share the latest teaching materials and contents. The three related government ministries (MEXT, MIC, and the Ministry of Economy, Trade and Industry) cooperate with the consortium's activities. In addition, 120 educational committees and 189 organizations participate in the consortium's activities as of January 2018.

The government ministries have also backed demonstration projects entitled "Project of programming education promotion for young people," carried out in 11 regional blocks in Japan, which aimed to nurture human resources with the ability to solve regional challenges. In the demonstration projects, 11 proposals were selected from the topics of "regional problem and programming," "making and programming," "traditional entertainment and programming," and so on. The results of the 11 projects showed that programming education activities changed the consciousness of those who cooperated and participated in the demonstration activities. This change indicated that programming education with a wide range of participants, including not only students but also parents, school teachers, educational boards, high school and university students serving as mentors, and the high schools and universities from which mentors are dispatched could be a well-founded regional activity.

In fact, the charter of the consortium states that its aim and purpose is to realize an "education process open to society," which nurtures in children the necessary skills and abilities to be creators of the future. It also stated that the three ministries, school stakeholders, and industries should work as one to build a support framework for teaching at schools, providing visiting lecturers and digital teaching materials suited to various on-site needs related to regional players and each area.

In addition to the collaborative organization described above, in which private companies and the board of education participate, the association ICT CONNECT 21 was established in 2015[12]. ICT CONNECT 21 promotes ICT utilization for the future style of learning through the activities of the Technical Standards Working Group and the Promotion Working Group, among others.

(2) Singapore: Providing competition events and new learning tools through collaboration between industry, government, and academia

[12] https://ictconnect21.jp/recruit-and-events/170309_establishment/

One of the characteristics of 21st-century ICT capability development in Singapore is the many available opportunities to extend IT talent through various extracurricular activities. For example, IMDA has supported various national infocomm competitions. These competitions cover a wide range of areas, including programming, development of mobile applications, networking, game design, and so on. The target age of participants also varies, as different competitions are available for students of elementary, secondary, and higher education levels. These competitions are conducted through collaboration between industry and academia.

Excellent students from some of those competitions are also entitled to participate in overseas competitions.

A notable contribution by Singaporean university Singapore Polytechnic is the "CoSpace Robot" system. This system includes a virtual robot, a real robot, and a simulator, and was developed by the university as a practical tool for STEM education. Users can design both the virtual and real robot using the same programming logic. CoSpace Robot is also one of the RoboCup/Junior divisions. A maximum of four people from each school can participate in the preliminary competition held in Singapore.

(3) Malaysia: Collaboration between industry, government, academia, and overseas partners to foster 21st-century ICT capabilities

Malaysia actively nurtures comprehensive 21st-century ICT capabilities. The country's approach features its comprehensive nature, which aims for effectiveness and efficiency.

Under governmental leadership, close relationships between industry, government, and academia have promoted both revision of the school curriculum and expansion of programming learning opportunities outside school (see Section 1-2 (3)). In addition, Malaysia welcomes overseas companies and institutions to participate in their projects and measures.

"Digital Maker Club" and "Digital Maker Champion," collaboratively promoted by MDEC and the Ministry of Education to support curriculum design in schools, are examples of such projects. Twenty schools among those that applied to the Digital Maker Champion program (open to elementary and junior high schools) were selected to introduce Digital Maker Hub and Digital Maker Clubs in school. Not only universities and telecom carriers but also Google and Microsoft were partners in supporting this measure.

Additionally, MDEC and the Ministry of Education conducted the “Code.org campaign” in schools nationwide for two weeks, from the end of October to November 2017, in cooperation with Code.org (see Section 3-1 (2)). A total of 120 thousand students from 1,200 schools participated in the campaign.

Conclusion - The role of industry, government, and academia in fostering 21st-century ICT capabilities

This chapter introduced the role of collaboration between industry, government, and academia in development of 21st-century ICT capabilities with respect to the following:

- Developing and offering new learning tools and services
- Introduction of independent CS subjects within a short time frame
- Various approaches in APT countries

As noted in Chapter 2, revision and strengthening of school curricula require improvement of teacher qualifications and tools and materials to support teaching of new subjects or learning items. Development of ICT equipment, software, and networks is a particularly important factor for fostering 21st-century ICT capabilities. At the same time, because technological innovation is rapid, it is generally difficult to properly and efficiently introduce such ICT equipment, software, and so on in schools, where time and expense are required to revise curricula and introduce new teaching materials and tools.

Under such circumstances, nonprofit organizations and companies can provide various learning tools and services. Such tools and services can be used not only from Western countries, but all countries worldwide. Teaching materials and tools developed by such companies and nonprofit organizations are adopted even within schools, not just as extracurricular activities outside school.

There is also movement to support and encourage introduction of high-quality teaching materials and tools through collaboration between companies and nonprofit organizations, schools, and administration.

Through such partnerships between industry and academia, and through networking between schools, efforts are being made to improve teacher quality and educational environments, which has improved the quality of education concerning 21st-century ICT capabilities and expanded its reach.

Furthermore, the U.K. case shows that collaboration among industry, nonprofit organizations, and academia can facilitate swift introduction of new independent computing subjects.

Based on the above, networking and collaboration between industry, government, and academia are considered to have synergistic effect by making full use of each entity's respective strengths. Following is a summary of some of such strengths of industry, government, and academia, and areas in which we believe they can contribute through collaboration.

Private sector (includes nonprofit organization and companies):

- Development of learning tools, services, and equipment utilizing the latest knowledge and expertise.
- Standardization of learning content.
- Awareness-raising through grassroots networking.
- Promotion of institutional reform activities, etc.

Governmental institutions:

- Coordination of networks between industry, government, and academia.
- Policy planning, legal system improvement, budget allocation, school curriculum revision, nationwide curriculum deployment, etc.

Academia:

- Theoretical development regarding 21st-century ICT capabilities
- Teacher education
- Promotion of cooperation and networking among schools, etc.

Collaboration not only improves the effectiveness and efficiency of 21st-century ICT capability development, but also furthers the progress of society as a whole toward next-generation society. In some noteworthy cases, countries including Malaysia and

Singapore reach to foreign nonprofit organizations and companies in their collaboration efforts, and some refer to corresponding efforts in other countries.

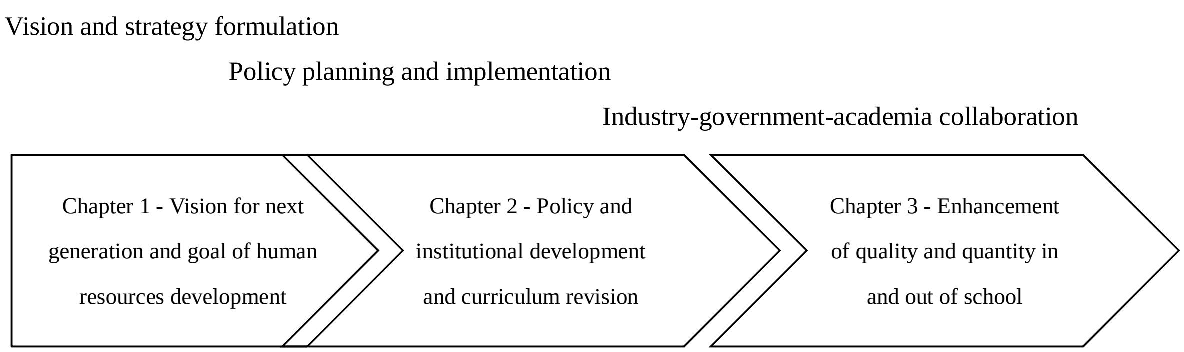
Conclusion - Fostering 21st-century ICT capabilities in the next generation in APT countries

As outlined in this book, movement to expand learning and educational opportunities to enhance ICT utilization skills at the primary education level is spreading from developed countries to middle-income countries. Given these efforts, the ability to utilize information and ICT is growing more common to all in comparison with past higher education (partly secondary education) plans that aimed to nurture human resources with talent, expertise, and skills in the ICT field.

In this book, we defined these capabilities as 21st-century ICT capabilities, and we introduced related activities and various approaches in each country studied. Although we found various approaches in each country, the following three elements are indispensable for nurturing 21st-century ICT capabilities:

- Formulation and sharing of vision
- Development of policies and institutional frameworks
- Cooperation between industry, government, and academia

Figure C-1 Elements for fostering 21st-century ICT capabilities



Source: Created by the author.

As mentioned in Chapter 1, it appears preferable to develop 21st-century ICT capabilities based on the country's next-generation industrial and social vision. These government-created visions and strategies will provide a sense of direction in policies and institutional development, and can be expected to positively affect collaboration between government agencies and local governments. Although each country discussed in Chapter 1 formulated a unique strategy or vision based on its own environment and socioeconomic situation, the three aspects shown in Table C-1 appeared as common broad classifications. Any country's strategy or vision can include these three aspects in whatever proportion is appropriate; the scope of this book's research survey resulted in the following organization shown in Table C-1.

Table C-1 Direction of vision for next-generation society on development of next-generation human resources

	Strengthen industrial competitiveness and innovation	Adapt to globalization	Create citizens of the digital society
United States	X		
United Kingdom	X		X
Finland		X	X
Japan	X		
Singapore		X	X
Malaysia		X	X
Thailand	X		X

Recent trends show that introduction of 21st-century ICT capabilities in primary and secondary education is growing full-fledged, and the third aspect in Table C-1 is becoming more important.

Chapter 2 covered the development of school curricula to nurture 21st-century ICT capabilities. The efforts of each country are roughly divided into four categories, listed below and shown in Table C-2.

- Establishing independent compulsory subjects (U.K., Australia, Malaysia)
- Expanding integrated STEM education (U.S., Thailand, Singapore)
- Converting to 21st-century skill type education (Finland, Japan, Australia)
- Combination of the above (Malaysia, Australia)

Table C-2 School curriculum development to build 21st-century ICT capabilities in each country

	CS compulsory independent course type	Integrated STEM type	21st-century skill type
United States		X	

United Kingdom	X		
Finland			X
Australia	X		X
Japan			X
Singapore		X	
Malaysia	X		X
Thailand		X	

In Chapter 3, we discussed the roles of industry-government-academia collaboration and networking in fostering 21st-century ICT capabilities. Characteristics of the collaboration in each country are shown in Table C-3.

Table C-3 Characteristics of industry-government-academia collaboration to foster 21st-century ICT capabilities in each country

	Characteristics
United States	Nonprofit organizations and companies contribute to expansion and quality improvement of 21st-century capability learning opportunities outside school. The federal government promotes improvement of STEM education.
United Kingdom	Close cooperation between industry, government, and academia facilitated introduction of independent subjects in primary and secondary within a short period of time. Companies contributed to large-scale introduction of learning tools and equipment.
Japan	The Prime Minister's Office initiative announced the plan to introduce programming education to primary school in 2020. Industry-government-academia cooperation organizations were formed to promote programming education regionally.
Singapore	Talent-enhancement type STEM education is typical. Recently, however, computational thinking was introduced in primary education.
Malaysia	Expansion of both in-school and extracurricular learning opportunities are promoted by government initiatives. Experience and expertise from overseas entities are actively sought.

Because the scope of this book was limited to a literature survey and interviews in the U.S., some countries of Europe (the U.K. and Finland), and some APT countries (Malaysia, Singapore, Thailand, and Myanmar), it does not cover all approaches to fostering 21st-century ICT capabilities. Still, this book showed a variety of approaches to serve as reference information for APT countries, assuming they will consider and improve their relevant measures, projects, and so on. The circumstances of school ICT environment development and the possibility of international cooperation were not sufficiently studied in this book, and will require further investigation and analysis.

Building relationships of information exchange and cooperative networks among APT countries and abroad will further enhance 21st-century ICT capabilities. As contributors to this APT publishing project, we sincerely hope that the contents of this book will be of aid in this endeavor.

[note]

[note]

[note]

Title: Approaches to Fostering 21st-Century ICT Capabilities for Future Generations in APT Countries

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