Design and Technology Education: An International Journal

29.2

Development of a new framework of Technology and Engineering Education by the Japan Society of Technology Education

Jun Moriyama, Hyogo University of Teacher Education, Japan
Toshikazu Yamamoto, Saitama University, Japan
Hiroyuki Muramatsu, Shinshu University, Japan
Hirotsugu Taguchi, Kumamoto University, Japan
Tadashi Ohtani, Tokyo Gakugei University, Japan
Ping Yang, Kumamoto University, Japan
Akira Kikuchi, Naruto University of Education, Japan
Koushi Ueno, Hakuoh University, Japan
Yoichi Miyagawa, Iwate University, Japan
Shigekazu Watanabe, National Institute for Educational Policy Research, Japan

Abstract
It is considered important to clarify the role of technology and engineering education for evolving STEM/STEAM education in each country. However, in Japan, unlike in other countries, the focus on STEAM education began after 2018, so the relevance of STEAM education to technology and engineering education has not yet been fully discussed. Therefore, the Japan Society of Technology Education (JSTE) tried to develop a new framework of technology and engineering education for promoting STEAM education in Japan prior to the revision of the National Curriculum. First, we conducted a survey on 1,656 Japanese junior high school students about the status of 'Technology' learning. As a result, it was shown that Japanese students have a positive attitude of 'Technology' classes. However, there is a lack of learning activities related exploring technology, and design problem-solving is not adequately linked to abilities for technological innovation and governance. From this, we developed a new framework focused on enhancing exploratory activities and problem-solving related to engineering. The framework included the Triple-Loop Model as the engineering design process, the connections between physical and cyber technologies within that scope, and the learning model of STEAM education that centred on the engineering design process with various connections among all subject areas. Lastly, we conducted a survey to evaluate the new framework on JSTE members (four-point scale, agreement rating). As a result, many received mean value of 3.00 or higher, showing that the participants agreed with the proposals. However, the concept of the term 'Engineering' (2.78) had a mean value of less than 3.00 and a larger SD than the others. Therefore, in the last version the concept of the term 'Engineering' was revised, and the framework was completed.

Keywords
The Japan Society of Technology Education, Technology and Engineering Education, new framework, Japan

Introduction

Background and purpose of the study

As STEM (Science, Technology, Engineering, Mathematics) / STEAM (Science, Technology, Engineering, Arts, Mathematics) education flourishes worldwide, the importance of technology and engineering education is increasing. The International Technology and Engineering Educators Association (ITEEA) states in the Standards for Technology and Engineering Literacy (STEL) that "Extensive changes have taken place in education in the past twenty years. There is an increased emphasis on design, and specifically on technology and engineering design, in the PreK-12 curriculum" (ITEEA, 2020, p.viii). However, the role of technology and engineering education in STEM/STEAM education is sometimes underestimated. In the STEL, it is also mentioned, "In spite of this recognition, the role that technology and engineering play, and should play, in the education of PreK-12 students is often narrowly defined and misunderstood" (p.viii). In such a situation, it is important to clearly define the role of technology and engineering education in STEM/STEAM education at an early stage for educational reform. This is one of the main reasons for the publication of STEL by ITEEA.

In the case of Japan, since 2019, there has been an increasing focus on STEAM education within the Ministry of Education, Culture, Sports, Science and Technology (MEXT, 2019). MEXT is paying attention to the characteristics of STEAM education as transdisciplinary learning that integrates STEM and Arts (MEXT 2019). Perignat and Katz-Buonincontro (2019) state there are a myriad of definitions for STEAM and the 'Arts'. One such theory is that of Yakuman (2010), who proposed STEAM education is an integrated educational theory that adds Arts to the traditional STEM education. Yakman defines STEAM as interpreting science and technology through engineering and the arts, based on mathematical elements, and she states the main objectives of this theory are as follows:

(i) Integration of Disciplines: It provides a more comprehensive education by integrating and interrelating the fields of science, technology, engineering, arts, and mathematics.

(ii) Promotion of Creativity: By incorporating arts, it enhances students' creativity and problem-solving skills.

(iii) Relevance to Real Life: It deepens the understanding of real-world problems, enabling students to tackle challenges they may face in society.

Yakman's STEAM education theory aims to eliminate the 'silo effect' of academic disciplines, fostering a learning environment where each field complements the others, thereby increasing students' interest and motivation to learn. In the case of Japan, based on Yakman's theory, MEXT defined STEAM education as "transdisciplinary learning that utilises learning from each subject to discover and solve real-world problems" [translation from Japanese] (MEXT, 2019). And they define the scope of Arts (the 'A' in STEAM) broadly, to include not only fine arts and culture but also life, economics, law, politics, ethics, and other areas of Liberal Arts.

It is highly likely that STEAM education will become an important concept in the revision of the next national curriculum in Japan. However, the approach to educational reform in Japan is unique, and there is a need to seamlessly connect the history of previous educational reforms with new concepts such as STEAM education. Therefore, it may be difficult to apply the ITEEA's STEL directly to Japan. It is likely that other countries with their own national curricula may face similar difficulties. In the context of Japan, it is necessary to have academic proposals that play a similar role to ITEEA's STEL in order to clarify the role of technology and engineering education in STEAM education.

For these reasons, the Japan Society of Technology Education (JSTE) initiated a project to develop a new framework for technology and engineering education in Japan. JSTE is an academic society that leads research in technology education in Japan. JSTE has already published "Technology Education in the 21st Century" (first edition) in 1999, followed by a revised edition in 2012, and illustrative examples of contents in 2014 as frameworks for technology education in Japan (JSTE, 1999, 2012, 2014). These documents proposed the principles, objectives, contents, and problem-solving processes of technology education in Japan. On the other hand, the revision of the national curriculum is deliberated upon by relevant subcommittees of the Central Council for Education (CCE) of MEXT, in response to consultations from the Minister of MEXT. For each subject area, specialized committees in the CCE consisting of Senior Specialist for Curriculum, university researchers, prefectural educational supervisors, schoolteachers, and other representatives are involved in the deliberations. Usually, academic societies are not directly involved in this process. However, in the case of technology education, the proposals by JSTE, such as "Technology Education in the 21st Century" (JSTE, 1999, 2012), have had a certain level of influence on the revision of the national curriculum. Ueno (2023) pointed out that during the revisions of the curriculum in 2008 and 2017, the president and vice-president of JSTE became members of the specialized committees. This inclusion facilitated the implementation of curriculum reforms based on the ideas presented in "Technology Education in the 21st Century."

Currently, discussions have begun in Japan regarding the revision of the next educational reform. It is expected that JSTE will continue to have a certain level of influence on this educational reform, like previous revisions. In fact, it has been more than 20 years since the first edition of "Technology Education in the 21st Century" was published in 1999, and during this time there have been significant changes in society and technology. Especially in recent years, there has been increasing emphasis on the Fourth Industrial Revolution and Connected Industries, highlighting the integration of new technologies such as artificial intelligence (AI), the internet of things (IoT), robotics, Big Data processing, and so on, with traditional industries such as agriculture and manufacturing. In Japan, this type of new society is called Society 5.0. Society 5.0 refers to a concept that the Japanese government aims to achieve, which represents a new type of society (Cabinet Office, 2016). Society 1.0 represents the hunting society, 2.0 represents the agricultural society, 3.0 represents the industrial society, and 4.0 represents the information society. Society 5.0 envisions a society where Society 1.0 to 3.0 are highly integrated with Society 4.0, aiming for sustainable development and the resolution of social challenges. In order to actualize Society 5.0, it is important to connect and integrate cyber technologies and physical technologies. This requires a highly integrated approach between these new technologies and existing industries. These changes in society have necessitated a reform of education. In response to these changes, JSTE has undertaken a revision of "Technology Education in the 21st Century" and has developed "The New Framework of Technology and Engineering Education for Creating a Next Generation Learning" [translated from Japanese] (JSTE, 2021).

In this paper, we report the details of this project. Then, we discuss the research question: What happens when academic society is involved in the design of the technology education curriculum?

Current Status of Technology Education in Japan

First, we introduce the current status of technology education in Japan, which was revised in the 2017 national curriculum (MEXT, 2017). Technology education, as general education in Japan, is positioned within the subject ‘Technology’ as part of the subject area of ‘Technology and Home Economics’ in the junior high school curriculum. In the elementary school curriculum, some learning activities include hands-on activities for making things and computer programming activities in various subject areas. However, these activities are not systematized as technology education. In high school, there is a subject called ‘Informatics’, but there are no other subjects that specifically deal with other areas of technology. Here, let’s focus on the junior high school subject ‘Technology’. The number of lessons of ‘Technology’ allocated for each grade level is 35 lessons per year (1 class is 50 minutes) in 7^{th} grade (13 years old), 35 lessons per year in 8^{th} grade (14 years old), and 17.5 lessons per year in 9^{th} grade (15 years old). In the revised national curriculum of 2017, the objectives of ‘Technology’ are as follows. Also, the learning contents of ‘Technology’ can be summarized as shown in Table 1 (note: this summary is edited by the authors).

Objectives

Fostering abilities that contribute to the creation of a better life and sustainable society through practical and experiential activities related to technology, utilizing a viewpoint and way of thinking of technology.

(i) To develop a foundational understanding of material processing, biological cultivation, energy conversion, and information technologies that are used in daily life and society; to acquire skills related to these technologies; and to gain a deeper understanding of the relationship between technologies, daily life, society, and the environment.

(ii) To develop technological problem-solving abilities, such as identifying problems related to technology within daily life and society, setting one’s own tasks, finding solutions, expressing ideas through drawing or other forms, producing (or cultivating), and evaluating and improving.

(iii) To cultivate practical attitudes for the proper and honest pursuit of technological devices and innovations to realize a better life and build a sustainable society.

The goal of learning in ‘Technology’ is for students to acquire the ability to evaluate, select, manage, operate, improve, and apply technology, fostering their creativity and problem-solving skills. Among these, the “ability to evaluate, select, manage, and operate technology” refers to the ability of technological governance, which is the multidimensional evaluation of the benefits and risks of technology in society and the democratic control of technological development for the future. Also, the “ability to improve and apply technology” represents the ability of technological innovation, which means the creation of new value in society by using technology. In this curriculum, especially, the construction of four learning contents and the concept of abilities for technological innovation and governance were influenced by JSTE's "Technology Education for the 21st Century" (2012).

In order to develop a new framework for technology and engineering education, we decided to understand how students are learning in the current national curriculum described above, and to examine the direction in which a new framework should go.

Table 1. Overview of Learning Contents of 'Technology' in Japan (Revised in 2017)

		Content A Material and Processing Technology	Content B Biological Technology	Content C Energy Conversion Technology	Content D Information Technology
1	(1)	Understanding the principles and mechanisms of technologies that supporting our daily life and society			
	(2)	Reading ingenuity of technological problem-solving that embedded in existing products or systems.			
2	(1)	Skills for fabrication, production, and cultivation.			
	(2)	Identifying problems, setting tasks, designing solutions and executing technnological problem-solving.			
3	(1)	Understanding the concepts of technology and the role of it in development of society.			
	(2)	Thinking of Evaluating, selecting, managing, operating, improving, and applying technology, and cultivating creative attitude for actualization of sustainable development of society.			

Note: In Content D, section 2(1)(2) in other contents are divided into 2(1)(2)"problem solving by programming with network technology" and 3(1)(2) "problem solving by programming with sensing and control technology". Therefore, 3(1) (2) in other contents is become 4(1)(2) in Content D.

Survey on actual status of students' awareness for learning 'Technology' in Japan

Purpose

We conducted a survey to understand Japanese junior high school students' awareness and learning situations in 'Technology' classes implemented under the current national curriculum.

Method

Subjects

The subjects were 1,656 7th to 9th grade students in Hyogo Prefecture, Japan.

Question Items

The questionnaire consisted of four categories to assess their awareness and experiences regarding 'Technology' classes. The concept of the items is as follows. See the Appendix for specific question items.

1.Awareness towards 'Technology' learning
- 1-1 Importance of learning technology
- 1-2 Joy of learning technology

1-3 Understanding of technology learning
1-4 Interest in technologies that support our daily life and society

Four-point scale: 4: very much, 3: a lot, 2: not much, 1: not at all
Each response being scored from 4 to 1.

2.Status of learning activities related to problem-solving
2-1 Active attitude towards learning in technology classes
2-2 Collaborative learning in technology classes
2-3 Linking own learning experiences with social issues

Four-point scale: 4: very much, 3: a lot, 2: not much, 1: not at all
Each response being scored from 4 to 1.

3. Status of students' problem-solving experiences
3-1 Exploring (inquiry, experimentation, and observation)
3-2 Planning and designing
3-3 Project management
3-4 Troubleshooting

Four-point scale: 4: very much, 3: a lot, 2: not much, 1: not at all
Each response being scored from 4 to 1.

4. Abilities acquired through learning
4-1 Abilities for technological governance
4-2 Abilities for technological innovation

Four-point scale: 4: Very much, 3: Fairly much, 2: Not much, 1: Not at all
Each response being scored from 4 to 1.

Data Analysis

For Items 1, 2, and 3, the mean score and standard deviation (SD) were calculated to determine the actual condition of the students' learning and awareness. After that, multiple regression analysis was conducted with Item 4 as the objective variable and Items 2 and 3 as explanatory variables. A path diagram (Figure 1) was drawn using significant standard partial regression coefficients obtained from the multiple regression analysis.

Result and Discussion

First, students' awareness towards 'Technology' learning is shown in Table 2, which indicates that they have a positive awareness of the importance of 'Technology' classes and perceive them as enjoyable and understandable.

Also, it is suggested that students have an interest in technologies that support our daily lives and society. The status of learning activities related to problem-solving is shown in Table 3. It is suggested that students are actively engaged in self-directed and interactive learning in 'Technology' classes. However, there is a slight weakness in awareness of linking their learning experiences to social issues.

The status of students' problem-solving experiences is shown in Table 4. From Table 4, it was indicated that students are engaged in problem-solving activities such as project management, planning and design, and troubleshooting in 'Technology' classes. However, it was found that students are not sufficiently engaged in exploratory activities such as inquiry, experimentation, and observation related to technology.

Table 2. Students' awareness towards 'Technology' learning.

Items	*Mean*	*SD*	*95%CI*	
			Lower	Upper
Importance of learning technology.	3,24	0,70	3,21	3,27
Joy of learning technology	3,35	0,66	3,32	3,38
Understanding of technology learning	3,08	0,71	3,05	3,11
Interest in technologies that support our daily life and society	3,05	0,69	3,02	3,08

N = 1656
4-point scale

Table 3. Status of learning activities related problem-solving.

Items	*Mean*	*SD*	*95%CI*	
			Lower	Upper
Active attitude for learning in technology classes	3,12	0,70	3,09	3,15
Collaborative learning in technology classes	3,25	0,72	3,22	3,29
To link own learning experiences with social issues	2,34	1,49	2,27	2,41

N = 1656
4-point scale

Table 4. Status of students' problem-solving experiences.

Items	*Mean*	*SD*	*95%CI*	
			Lower	Upper
Exploring(inquiry, experimentation, and observation)	2,64	0,89	2,60	2,68
Planning and designing	3,18	1,34	3,12	3,25
Project management	3,22	0,67	3,19	3,25
Troubleshooting	3,18	1,34	3,12	3,25

N = 1656
4-point scale

A multiple regression analysis was conducted to examine the impact of these learning activities on students' abilities for technological innovation and governance (Figure 1). Incidentally, multiple regression analysis is a statistical method used to investigate how multiple independent variables (predictors) collectively influence a single dependent variable (outcome).

By using multiple regression analysis, we can quantify and assess the causal relationships between several predictor variables and a target variable. As a result, unfortunately, overall, the influences of learning activities on the abilities for technological innovation and governance were weak. Also, the results suggest that problem-solving activities related to planning and design, as well as troubleshooting, are not contributing to the development of the students' abilities. It is considered that this is due to the limited design activities, which may be restricted to activities such as selecting and improving models prepared by the teacher.

Based on these results, the following points can be noted regarding the actual status of students in 'Technology' classes in Japan. Japanese students have a positive perception of 'Technology' classes; however, there is a lack of sufficient learning activities that involve exploring technology. Additionally, the most important element of technology education, which is design problem-solving, is not adequately linked to the development of abilities for technological innovation and governance. From this point of view, it is believed that the future of technology education in Japan should focus on enhancing exploratory activities and problem-solving related to engineering. Considering the role of STEM/STEAM education moving forward, it is necessary to prioritize design learning as the core and foster abilities for technological innovation and governance.

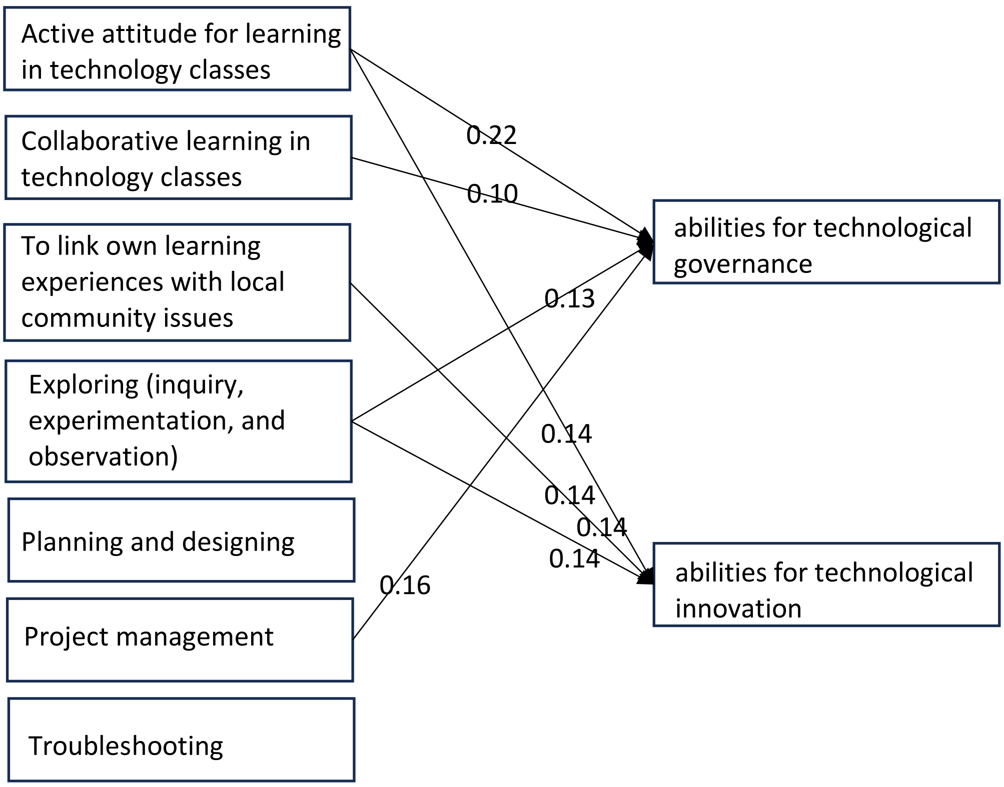

Figure 1. Causal relationship toward students' abilities for technological innovation and governance.

Development of New Framework for Technology and Engineering Education

In light of this, JSTE initiated a project to revise the "Technology Education in the 21st Century" curriculum in 2017. As part of JSTE's initiatives, we first established a 'Technology Education Ideathon' session. 'Ideathon' is a term coined by combining 'idea' and 'marathon', which refers to a creative discussion platform where participants continuously generate various ideas. JSTE has been organizing 'Ideathon' on an annual basis since 2017. Additionally, the project has held four symposiums during JSTE's annual conferences from 2019 to 2022, in order to gather various opinions from JSTE's members. In this process, the name of 'Technology Education' was changed to 'Technology and Engineering Education'. Then, the project reached the milestone of publishing "The New Framework for Technology and Engineering Education to Create the Next Generation of Learning" (NGTE) in 2021.

Objective of Technology and Engineering Education in NGTE

NGTE divides technology and engineering education into two categories for discussion: professional education for cultivating technological experts such as engineers, technologists, etc., and general education for fostering technology and engineering literacy among all citizens. Particularly, NGTE focuses on technology and engineering literacy education. NGTE defines acquiring the abilities for technological innovation and governance as the final goal of technology and engineering literacy. An overview of the objectives to achieve this goal is summarized in Table 5.

In Table 5, technology and engineering literacy is positioned on the left side. It shows how this literacy enhances generic competences. It shows that technology and engineering literacy plays an important role not only in developing abilities related to technology and engineering but also in developing generic competences at three layers: as "individual," "engaging with others," and "life and social development." The envisioned future shape of students who have learned technology and engineering education are "A: Technologically literate citizens," "B: Responsible users of technology," "C: Creative individuals as technological problem-solvers," "Lifelong learners about technology," "Decision-makers related to technology," "Eggs of engineers," and "Promoters of culture to actively support technological development in society." These images represent the desired outcomes for students in technology and engineering education.

Table 5. Overview of Objectives of Technology and Engineering Education in NGTE

Technology and Engineering Literacy	**Competencies enhanced by technology and engineering literacy**		
	As individual	Engaging with others	Life and social development
Scientific understandings of technology and engineering Understandings of interconnection between technology and society, environment, economy and so on.	Integrative recognition and application abilities in both STEM and Arts	logical communication (expression, share, argument)	Career development and self-actualization
Development of abilities to technological problem-solving and engineering.	design thinking critical thinking logical thinking computational thinking system thinking GRIT etc	cooperative skills collaborative skills menbership leadership followership etc	Abilities to move various projects forward in lifelong
Development of abilities to participate in technological governance in society.	Jadgment abilities Decision making abilities Fairness Citizenship etc	Abilities to engage in democratic and constructive dialogue	
Development of abilities to participate in technological innovation in society.	Creativity Proposal skills etc	Open mind Reciprocal relations etc	Abilities for building democratic and sustainable societies

Scope of Technology and Engineering Education in NGTE

NGTE has strengthened the following two points, considering the content structure of Japan's previous technology education. First, NGTE incorporated elements of engineering science in order to emphasize problem-solving through the exploration of technology by establishing the relevance between each content and its underlying academic discipline. Secondly, NGTE has enhanced the connections between technology and other diverse areas of expertise to enable students to create new value in a VUCA (Volatile, Uncertain, Complex, Ambiguous) society. This has been incorporated into the learning content as 'Technological Systems', emphasizing the interplay between technology and various other domains in society. Especially, we addressed the integration of cyber technologies and physical technologies based on the concept of Society 5.0. We believe these contents are linked to the abilities for technological innovation and governance. The proposed scope of technology and engineering education in NGTE is shown in Figure 2.

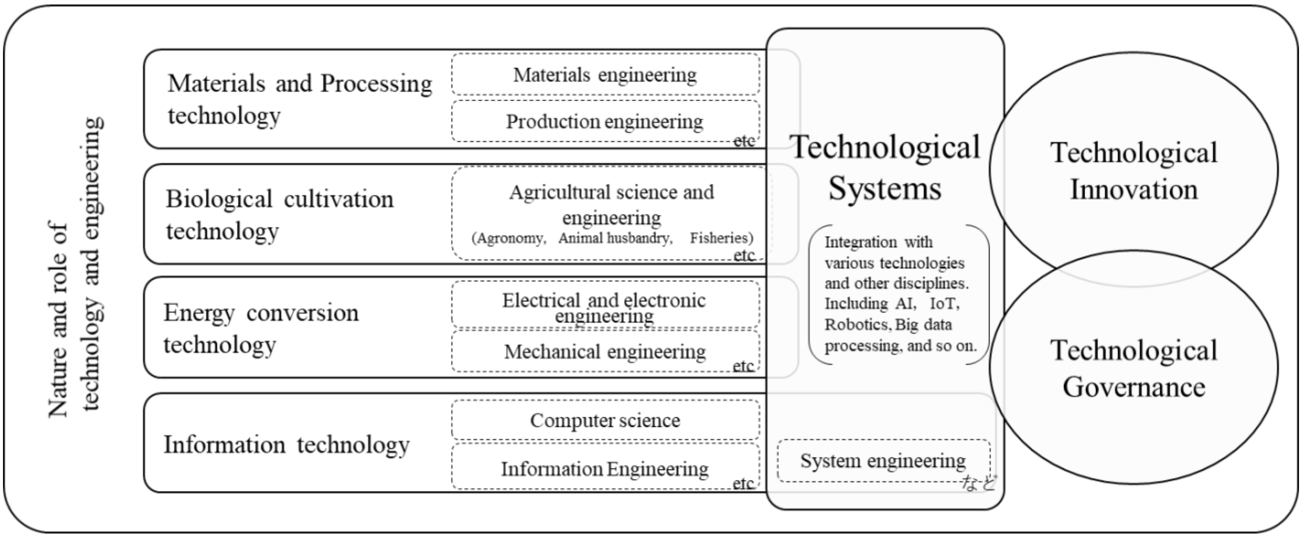

Figure 2. Scope of Technology and Engineering Education in NGTE.

In Figure 2, "understanding of the nature and roles of technology" is positioned to cover the whole scope. On top of that, individual technologies such as "materials and processing technology," "energy conversion technology," "biological cultivation technology," and "information technology" are positioned. Within this structure, engineering sciences, which are the background disciplines for each technology, such as materials engineering, electrical and electronic engineering, agricultural science, computer science, and so on, are positioned. Furthermore, as content that spans individual technologies, 'Technological Systems' is positioned. This content includes AI, IoT, robotics, Big Data processing, and more, aiming to integrate cyber and physical technologies. We aim to connect this learning to technological innovation and governance in order to foster the ability to create new value through technology and enable democratic steering in the direction of technology development.

Triple-loop model of Engineering Design Process in NGTE

As the results of the above survey have shown, there were issues regarding Japanese students not having sufficient learning experiences to explore the principles and mechanisms of technologies, and they could not apply the design process to their technological innovation and governance. To address these issues, we proposed the Triple Loop Model of the Engineering Design Process (Figure 3). Note: in the diagram below, 'PDCA' stands for Plan, Do, Check, Action, and 'STPD' stands for See, Think, Plan, Do, referring to different management cycles.

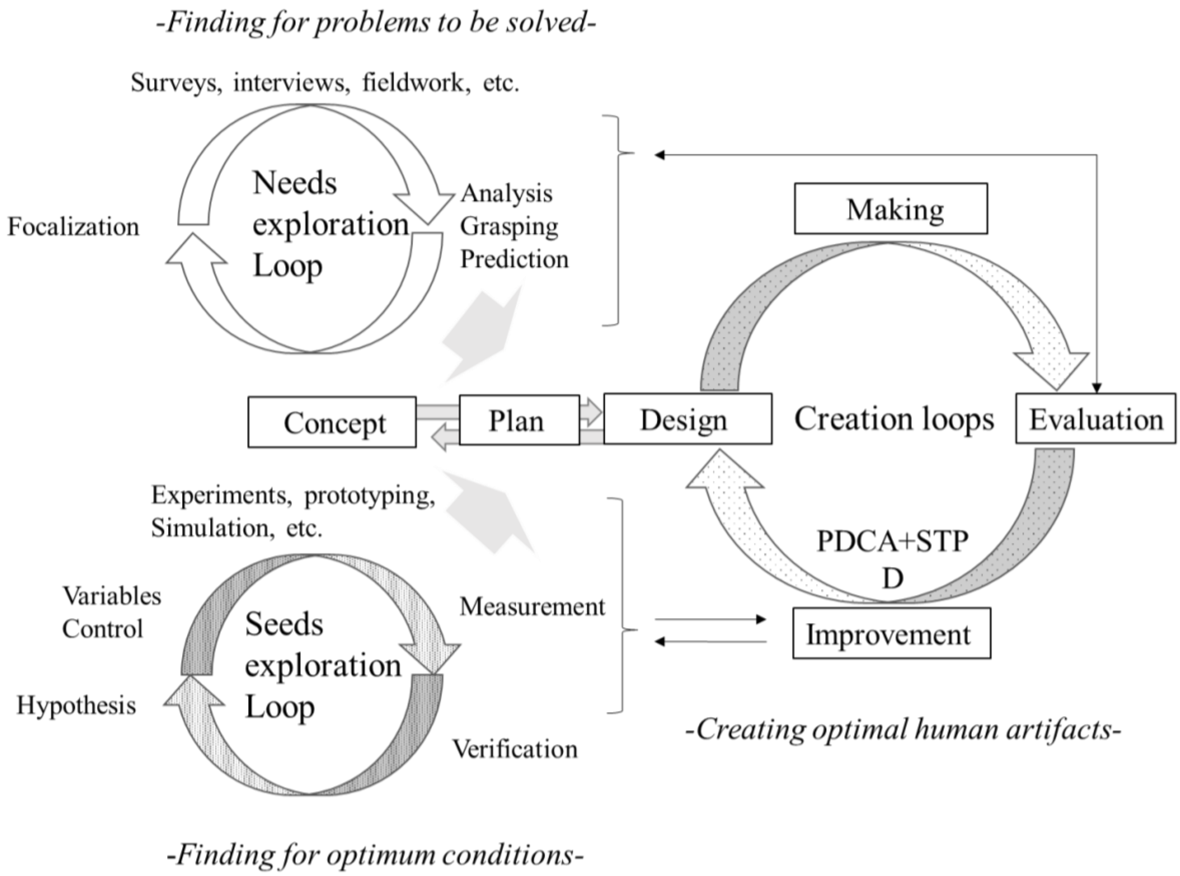

Figure 3. The Triple Loop Model of engineering design process in NGTE.

The Triple Loop Model illustrated an engineering design process that is constructed from iterative interaction of three loops such as Needs Exploration Loop, Seeds Exploration Loop, and Creation Loop. In the Needs Exploration Loop, students will utilise various methods such as surveys, interviews, or fieldwork and analyse various materials and data in order to identify problems, set tasks, and clarify users' needs. In the Seeds Exploration Loop, students set variables and explore optimal conditions for technological problem-solving. Furthermore, students engage in activities such as prototyping and simulations to devise optimal designs. In the Creation Loop, students match both 'needs' and 'seeds', and they design what should be created by optimisation thinking and make appropriate products or systems.

A Learning Model of STEAM Education in NGTE

Finally, the Learning Model of STEAM education that centred on the engineering design process in NGTE is shown in Figure 4.

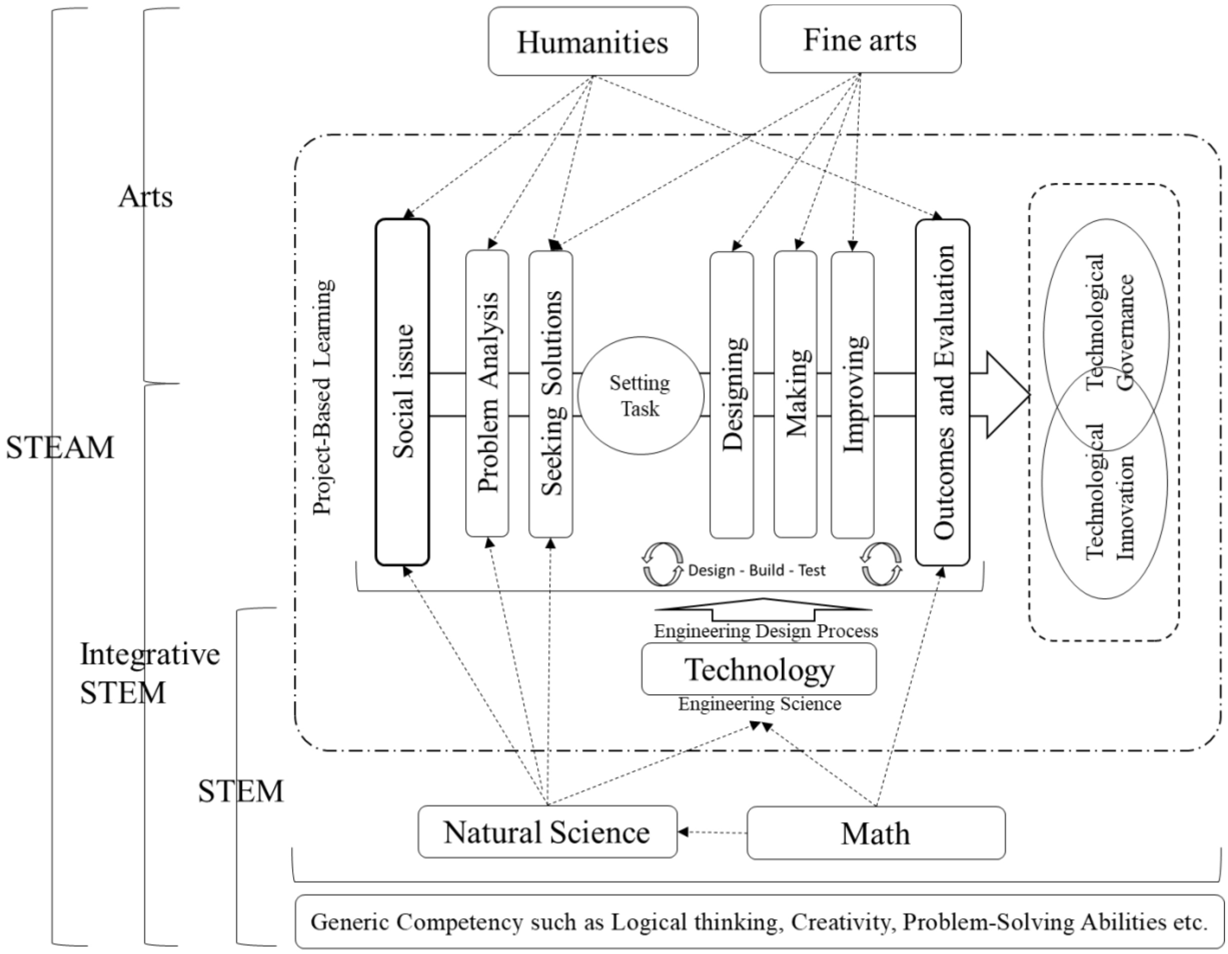

Figure 4. Learning Model of STEAM education that centred engineering design process in NGTE.

Essentially, technology and engineering play an important role in bridging the gap between natural science and society/culture through the design process. Therefore, in the context of STEAM education, technology and engineering literacy play an important role in connecting the disciplines of science, arts, and mathematics. It serves as a link that integrates these disciplines and makes STEAM education practices more holistic and comprehensive. In general, in STEAM education with project-based learning, there are opportunities for students to create both technological artefacts and non-technological outcomes. In NGTE, we focused on the former, and have envisioned a practical model of STEAM education that centred on engineering-based problem-solving through transdisciplinary learning across all subjects. This learning model is summarized in Figure 4. The model specifically focuses on setting up learning activities for creating technological artefacts such as useful products or systems that may be able to solve authentic problems in our society. Of course, there are various models of STEAM education. This is an example of one that can be implemented in 'Technology' classes or 'Period of Integrated Study' in Japan's national curriculum.

Evaluation of NGTE

To evaluate the developed NGTE (draft version), a symposium was held with JSTE members, and a survey was conducted for evaluation. Responses were scored on a 4-point scale from “very much agree” to “do not agree at all” for each proposal, with each response being scored from 4 to 1. The neutral point between agreement and disagreement was 2.50. Here, the high mean value indicates the degree of agreement, and the SD indicates the degree of scattering of opinions (Table 6). Most of the proposals had a mean value of 3.00 or higher, indicating that the participants agreed with the proposals. However, the expression of the concept of the term “engineering” (2.78) had a mean value of less than 3.00 and a larger SD than the others.

The expression of the concept of the term ‘Engineering’ in the draft version was: “Engineering is the scientific process of creating (producing, developing, inventing) optimal artefact systems to realise human needs, and the knowledge systems (disciplines) involved in realising this process.”

Table 6. Result of Evaluation on NGTE.

Items	*Mean*	*SD*	*95%CI*	
			Lower	Upper
Concept of Technology and Engineering Literacy in NGTE	3,27	0,76	3,11	3,43
Concept of the term "Technology" in NGTE	3,20	0,81	3,03	3,37
Concept of the term "Engineering" in NGTE	2,78	0,97	2,58	2,98
Objectives of Technology and Engineering Education in NGTE	3,24	0,71	3,09	3,39
Scope of Technology and Engineering Education in NGTE	3,30	0,66	3,16	3,44
Triple-loop model of Engineering Design Process in NGTE	3,23	0,74	3,08	3,38
A Learning Model of STEAM Education in NGTE	3,01	0,80	2,85	3,18

N = 90
4 point scale

We considered the expression of this term in the draft version was not sufficient as an explanation of this complex word. Therefore, we decided to change this expression in the final version of NGTE. The revised expression is as follows:

> *Engineering is a scientific problem-solving strategy for creating (production, development, and invention) optimal human-made products to realise human needs, and the knowledge systems related to the realisation of these problem-solving strategies. The knowledge system in engineering is the science related to technology,*

which can be referred to as engineering science. On the other hand, the design process is the process of applying a systematic problem-solving strategy to select a final idea from among several possible solutions, while clarifying evaluation criteria and constraints, to satisfy human needs by applying design thinking. The design process to optimise technology using the knowledge in engineering science can be called the engineering design process.

Using this expression, we provided a comprehensive description of this complex concept by incorporating both engineering science and the engineering design process.

Discussion

In this paper, we reported how the JSTE developed the new framework for technology and engineering education in Japan. As a result, we showed the current status of Japanese students, indicating that they have a positive perception of 'Technology' classes; however, there is a lack of sufficient learning activities involving the exploration of technology, and design problem-solving is not adequately linked to the abilities for technological innovation and governance. In light of these issues in students' learning and changes in society, we developed a new framework that focused on enhancing exploratory activities and problem-solving related to engineering. The proposal included the Triple-Loop Model as the engineering design process, the connections between physical and cyber technologies in that scope, and the learning model of STEAM education that centred on the engineering design process with various connections among all subject areas.

Zuga (1989) points out that there are five categories in curriculum design and development in technology education: (a) technical performance or processes; (b) academic focus on the specific body of knowledge relating to industry and technology; (c) intellectual processes that concentrate on critical thinking and problem solving; (d) social reconstruction through realistic or real-world situations; and (e) personal, learner-centred focus on individual needs and interests. Applying these categories to the NGTE, the engineering design process based on the Triple-Loop Model (Figure 3) covers (c) intellectual processes that concentrate on critical thinking and problem solving, (a) technical performance or processes, and (e) personal, learner-centred focus on individual needs and interests. The Triple-Loop Model itself is a direct element of (c) intellectual processes in engineering activities. Setting topics according to students' interests and concerns in projects using this model leads to (e) personal, learner-centred focus. Additionally, creating prototypes in projects relates to (a) technical performance or processes. Also, the scope structure that connects physical and cyber technologies in the NGTE, and the STEAM education model centred on engineering activities, are linked to societal changes in Japan aimed at realising Society 5.0. Therefore, they cover (d) social reconstruction through realistic or real-world situations. Additionally, this scope is related to (b) academic focus on the specific body of knowledge relating to industry and technology, as it describes the connection with engineering science within each content area in Figure 2. The NGTE thus aligns well with the five categories involved in curriculum development in technology education proposed by Zuga.

Here, the significance of this study is discussed from a meta-perspective. It concerns the role of researchers and academic societies in the revision of the national curriculum. The process presented in this paper can be organised as follows. The first step is to ascertain the current situation of learners who have studied in the current national curriculum. The second step is to interpret the current situation of these learners in relation to the direction of curriculum revision linked to social changes. The third step is to conceive and concretize the proposed curriculum revision to bridge the gap between the current situation of these learners and the competencies required by the next generation.

Currently, this is the third step, but a fourth step, involving the concrete revision of the national curriculum, is forthcoming. In the first step, academic insights are needed to determine the content and methodology of the survey and analyse it scientifically. This is an issue that academic societies should address. In the second step, the MEXT will set the direction for a major revision of the national curriculum, based on national policy and societal changes. It is important to interpret the gap between this direction and the actual situation of the identified learners. In the third step, the academic society will develop a curriculum standard to serve as a reference for the revision of the national curriculum, which will occur in the fourth step. This is the NGTE presented in this paper. The fourth step, as mentioned in the introduction, will be carried out by the Council of the MEXT. It is believed that the participation of academic societies here will enable the concept of curriculum standards developed in the third step to be reflected, to a certain extent, in the revision of the national curriculum.

In this study, the first and third steps were undertaken by academic societies (JSTE), and Senior Specialist for Curriculum from the MEXT were involved in the project. The second step is a more senior decision-making process within the MEXT, so it is not easy for members of academic societies to participate in the project at present. However, in the fourth step, members of academic societies are expected to participate in working groups for revising technology education curriculum. This scheme of collaboration between administrative bodies and academic societies to revise the national curriculum is considered to be particularly important in the development of technology education curriculum, which are susceptible to updates in learning content and changes in the required competencies.

Future tasks

We intend to use the NGTE to challenge the next educational reform in Japan. We would like to report on the process of this in a future. However, the Scope of Technology and Engineering Education, Triple-Loop Model and STEAM Learning Model are still hypothetical at this stage. It will be necessary to make clear the effects of these strategies through classroom practice. Wicklein (1997) states that there is a gap between what technology education curricula aim to teach and what is actually practised in classrooms. According to him, while educators advocate for teaching critical thinking and problem-solving, classrooms often use rigid models and focus heavily on technical skills. Despite the emphasis on understanding technology's societal and environmental impacts, this aspect is often neglected in favour of specific skill development. In our project, we proposed The NGTE as a new framework for technology education. However, to effectively implement practices based on this curriculum, it is essential to reform teacher education and training. This will be the fifth step. We plan to address these challenges moving forward.

Notes

This article is based on a conference paper presented at the PATT40 Liverpool 2023 conference and is aligned with Strand 2: exploring and advancing teaching and learning for design and technology education (Moriyama et al., 2023).

Also, this project received financial support from the Grants-in-Aid for Scientific Research (Grant No. 18H01014) provided by the MEXT, with Jun Moriyama Ph.D. serving as the principal researcher.

References

Cabinet Office, Government of Japan (2016). *Society 5.0*. https://www8.cao.go.jp/cstp/society5_0/ [In Japanese]

Everitt B.S. and Hothorn T., *A Handbook of Statistical Analyses Using R*, https://cran.r-project.org/web/packages/HSAUR/vignettes/Ch_multiple_linear_regression.pdf

International Technology and Engineering Educators Association (2020). *Standards for Technology and Engineering Literacy* [electronic document]. Retrieved from https://www.iteea.org/stel [accessed 29/08/2024]

Japan Society of Technology Education (2021). *The New Framework of Technology and Engineering Education for Creating a Next Generation Learning*, https://www.jste.jp/main/data/New_Fw2021.pdf [In Japanese]

Japan Society of Technology Education (1999). *Technology Education in the 21st Century*, https://www.jste.jp/main/data/21te.pdf [In Japanese]

Japan Society of Technology Education (2012). *Technology Education in the 21st Century (Revised Version in 2012)*, https://www.jste.jp/main/data/21te-n.pdf [In Japanese]

Japan Society of Technology Education (2014). *Technology Education in the 21st Century (Contents for Technology Education as General Education in each developmental Stage)*, https://www.jste.jp/main/data/21te-nex.pdf [In Japanese]

Ministry of Education, Culture, Sports, Science and Technology, Government of Japan (2019). *Promotion of cross-curricular learning as STEAM education*, https://www.mext.go.jp/a_menu/shotou/new-cs/mext_01592.html [In Japanese]

Ministry of Education, Culture, Sports, Science and Technology, Government of Japan (2017). Technology and Home Economics, *The Course of Study for Junior High School*, https://www.mext.go.jp/a_menu/shotou/new-cs/youryou/chu/ [In Japanese]

Moriyama, J., Yamamoto, T., Muramatsu, H., Taguchi, H., Yang, P., Otani, T., Miyagawa, Y., Kikuchi, A., Ueno, K., & Watanabe, S. (2023). A New Framework of Technology and Engineering Education Proposed by the Japan Society of Technology Education. *Proceedings of the 40th Pupils' Attitudes Towards Technology Conference*, Liverpool John Moores University, Liverpool, United Kingdom, 31 October – 3 November. Retrieved from https://openjournals.ljmu.ac.uk/PATT40/article/view/927

Ueno, K. (2023). Chapter 2: Educational Reform in Technology Education and the Japan Society of Technology Education, *Development of Next Generation Technology and Engineering Education Framework for linking Recognition science and Design science, Final Report of the Grants-in-Aid for Scientific Research* (Grant No. 18H01014), http://www.jste.jp/techedu/project/jste-ideason-KAKEN/FinalReport20230307.pdf (In Japanese)

Perignat, E. & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity, 31*, 31-43

Yakman, G. (2010). *What is the point of STE@M? – A Brief Overview* [electronic document]. Retrieved from https://www.researchgate.net/publication/327449281_What_is_the_point_of_STEAM-A_Brief_Overview [accessed 29/08/2024]

Wicklein, R.C. (1997). Curriculum Focus for Technology Education, *Journal of Technology Education, 8*(2), 71-78.

Zuga, K. F. (1989). Relating technology education goals to curriculum planning. *Journal of Technology Education*, 1(1), 34-58.

Appendix

Specific question items

1. Awareness towards 'Technology' learning
   1-1 Do you think learning in technology classes is important?
   1-2 Is learning in technology classes fun?
   1-3 Can you understand the learning content in technology classes?
   1-4 Are you interested in the technology that supports daily life and society?

2. Status of learning activities related to problem-solving
   2-1 Do you have an active attitude in technology classes?
   2-2 Are you learning collaboratively in technology classes?
   2-3 Are you linking your learning experiences in technology classes to issues in daily life and society?

3. Status of students' problem-solving experiences
   To what extent have you engaged in the following problem-solving experiences in technology classes?
   3-1 Exploring (inquiry, experimentation, and observation)
   3-2 Planning and designing
   3-3 Project management
   3-4 Troubleshooting

4. Abilities acquired through learning
   4-1 Do you think you have acquired abilities for technological governance through learning in technology classes?
   4-2 Do you think you have acquired abilities for technological innovation through learning in technology classes?