# A New Framework of Technology and Engineering Education Proposed by the Japan Society of Technology Education

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## ABSTRACT

In this paper, a new framework for technology and engineering education which was proposed by the Japan Society of Technology Education (JSTE) was introduced. We conducted a survey on Japanese junior high school students about status of "Technology" learning. As a result, it was indicated that Japanese students have a positive perception of "Technology" classes, however, there is a lack of learning activities related exploring technology, and design problem-solving is not adequately linked to the 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 proposal includes the Triple-Loop Model as engineering design process, the connections between physical and cyber technologies in that scope., and the learning model of STEAM education that centred engineering design process with various connections among all subject area.

*Key Words: The Japan Society of Technology Education, Technology and Engineering Education, Proposal of new framework, Japan*

## 1. INTRODUCTION

As STEM/STEAM (Science, Technology, Engineering, Mathematics, /and Arts) 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) as "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). 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." 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 big 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). In particular, MEXT is paying attention to the characteristics of STEAM education as transdisciplinary learning that integrates STEM and Arts (MEXT 2019). 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 of educational reform in Japan are 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. Therefore, 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 lead researches 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 process 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 the MEXT, in response to consultations from the Minister of MEXT. For each subject area, specialised committees in the CCE consisting of university researchers, prefectural educational supervisors, school teachers, and other representatives are involved in the deliberations. Usually, academic societies are not directly involved in this process. However, in case of technology education, the proposal by JSTE such as "Technology Education in the 21st Century" (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 specialised 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, similar to previous revisions.

In fact, it has been more than 20 years since the first edition of "Technology Education in the 21st Century" that 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, Connected Industries, highlighting the integration of new technologies such as AI, IoT, robotics, Big Data processing and so on with traditional industries such as agriculture, manufacturing, and so on. In Japan, this type of new society is called as Society 5.0. Society 5.0 refers to a concept that the Japanese government aims to achieve, which represents a new type of society. 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 of cyber technologies and physical technologies. This requires for 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." In this paper, we introduce the details of this project. The authors were key members of this project in JSTE.

## 2. CURRENT STATUS OF TECHNOLOGY EDUCATION IN JAPAN

### *2.1. Objectives and Contents of Current Technology Education in Japan (Revised in 2017)*

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 junior high school curriculum. In 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 systematised 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 are 35 lessons per year (1 class is 50 minutes) in 7th grade (13 years old), 35 lessons per year in 8th grade (14 years old), 17.5 lessons per year in 9th grade (15 years old). In the revised national curriculum of 2017, the objectives of "Technology" are as follows:

*2.1.1. Objectives:*

(i) Fostering abilities that contribute to the creation of a better life and sustainable society through practical and experiential activities related to technology, utilizing a view-point and way of thinking of technology.

(ii) (1) To develop foundational understanding of material processing, biological cultivation, energy conversion, and information technologies that are utilized in daily life and society, to acquire skills related to these technologies, and to gain deeper understanding of relationship between technologies and daily-life, society, and the environment.

(iii) (2) To develop technological problem-solving abilities such as to identify problems related to technology within daily life and society, set one's own task, finding solution, expressing through drawing or other forms, producing (or cultivating), and evaluating and improving.

(iv) (3) To cultivate practical attitudes for appropriate and honest pursuit of technological devices and innovations to realise a better life and build a sustainable society.

Also, the learning contents of "Technology" can be summarized as shown in Table 1 (this summary is edited by the authors.).

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

| | | Content A<br>Material and Processing Technology | Content B<br>Biological Technology | Content C<br>Energy Conversion Technology | Content D<br>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.

The goal of this 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, "ability to evaluate, select, manage, and operate technology" refers to the ability of technological governance, which is multidimensional evaluation of benefits and risks of technology in society and democratic controlling of technological development for future. Also, the "ability to improve and apply technology" represents the ability of technological innovation, which means creation of new value in society by using technology. In this curriculum, especially, the construction of 4 learning contents and the concept of abilities for technological innovation and governance were influenced by JSTE's "Technology Education for the 21st Century" (2012 edition).

### *2.2. Survey on actual status of students' awareness for learning "Technology"*

We conducted a survey on the learning situation of "Technology" among Japanese junior high school students (MORIYAMA et.al 2018). The subject was 1,656 7th to 9th grade students in Hyogo Prefecture, Japan. The questionnaire consisted of four items to assess their awareness and experiences regarding "Technology" classes. First, students' awareness towards "Technology" learning is shown in Table 2. Table 2 indicate that students have a positive awareness of the importance of "Technology" classes and perceive them as enjoyable and understandable. Also, it is suggested that students have 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* |
|---|---|---|
| Importance of learning technology. | 3.24 | 0.70 |
| Joy of learning technology | 3.35 | 0.66 |
| Understanding of technology learning | 3.08 | 0.71 |
| Interest in technologies that support our daily life and society | 3.05 | 0.69 |

*N* = 1656
4 point scale

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

| Items | *Mean* | *SD* |
|---|---|---|
| Active attitude for learning in technology classes | 3.12 | 0.70 |
| Collaborative learning in technology classes | 3.25 | 0.72 |
| To link own learning experiences with social issues | 2.34 | 1.49 |

*N* = 1656
4 point scale

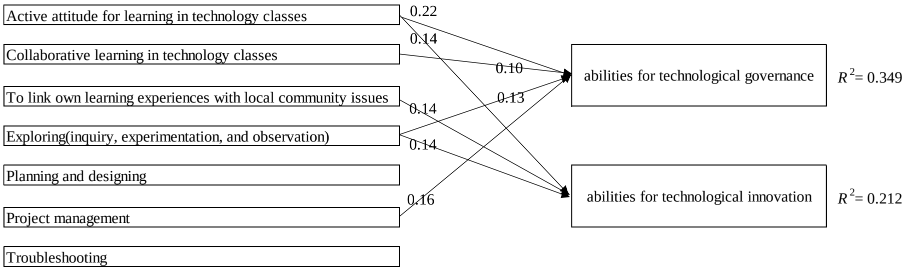
*Table 4.*
*Status of students' problem-solving experiences*

| Items | *Mean* | *SD* |
|---|---|---|
| Exploring(inquiry, experimentation, and observation) | 2.64 | 0.89 |
| Planning and designing | 3.18 | 1.34 |
| Project management | 3.22 | 0.67 |
| Troubleshooting | 3.18 | 1.34 |

*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 to 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 any contributing to develop 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.

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




Based on these results, the following points can be noted regarding the actual status of students in "Technology" classes in Japan. That is, Japanese students have positive perception of "Technology" classes, however, there is a lack of sufficient learning activities that involve exploring technology, and the most important element of technology education, which is design problem-solving, is not adequately linked to the development 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 the abilities for technological innovation and governance.

## 3. "TECHNOLOGY EDUCATION IN THE 21ST CENTURY" PROJECT

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 organising "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 to publish "the New Framework for Technology and Engineering Education to Create the Next Generation of Learning" (NGTE) in 2021.

### *3.1. 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. And particularly, NGTE focuses on technology and engineering literacy education. NGTE defined that acquiring the abilities for technological innovation and governance is considered as final goal of technology and engineering literacy. An overview of the objectives to achieve this goal are summarised as in Table 5.

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

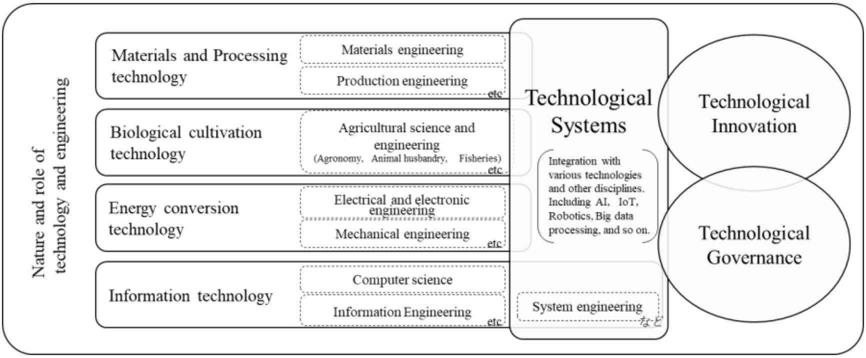
| Technology and Engineering Literacy | Competencies enhanced by technology and engineering literacy | | |
|---|---|---|---|
| | as individual | Engaging with others | Life and social development |
| ✓Scientific understandings of technology and engineering<br><br>✓Understandings of interconnection between technology and society, | 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<br>critical thinking<br>logical thinking<br>computational thinking<br>system thinking<br>GRIT<br>etc | cooperative skills<br>collaborative skills<br>menbership<br>leadership<br>followership<br>etc | Abilities to move various projects forward in lifelong |
| ✓Development of abilities to participate in technological governance in society. | Jadgment abilities<br>Decision making abilities<br>Fairness<br>Citizenship<br>etc | Abilities to engage in democratic and constructive dialogue | |
| ✓Development of abilities to participate in technological innovation in society. | Creativity<br>Proposal skills<br>etc | Open mind<br>Reciprocal relations<br>etc | Abilities for building democratic and sustainable societies |

In Table 5, technology and engineering literacy is positioned on the left side. It shows how this literacy enhance generic competences. It indicates 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 leant technology and engineering education are "A: Technologically literate citizens", "B: Responsible users of technology", "C: Creative individuals as technological problem-solver", "Lifelong learners about technology", "Decision-makers related to technology", "Eggs of engineers", "Promotors of culture to actively support of technological development in society." These images represent the desired outcomes from students in technology and engineering education.

### *3.2. 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 technology, or 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 thought 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*

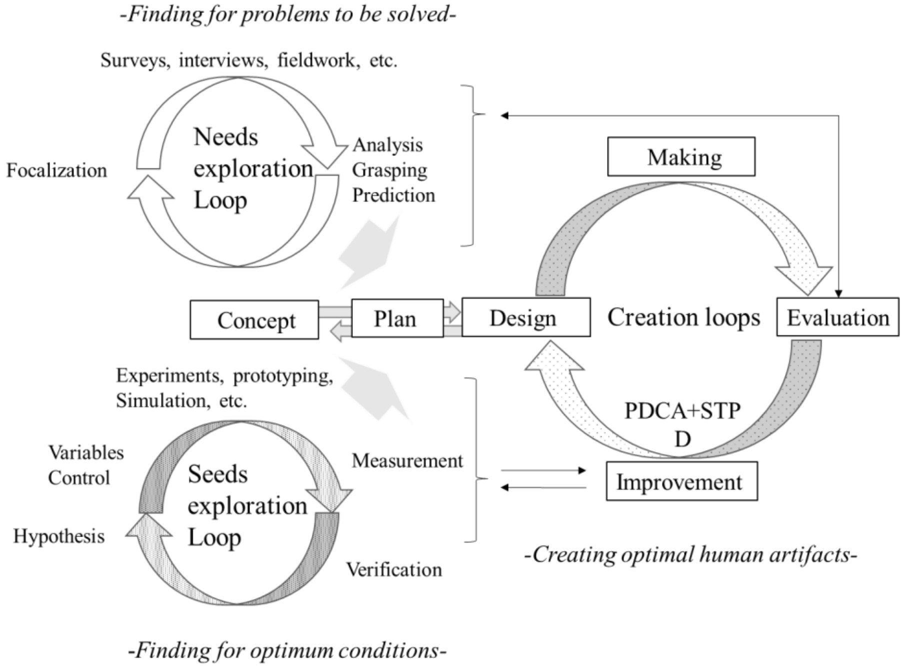



In Figure 2, "understanding of nature and roles of technology" is positioned to cover the whole scope. On of that, individual technology such as "materials and processing technology", "energy conversion technology", "biological cultivation technology", and "information technology" are positioned. Within this construction, engineering science, which is background discipline for each technology, such as materials engineering, electrical and electronic engineering, agriculture science, computer science and so on, is positioned. Furthermore, as content that across individual technology, "Technological Systems" is positioned. This content includes AI, IoT, Robotics, Big Data processing, and more, aims to integrate between cyber and physical technologies. And we aim to connect these learning to technological innovation and governance in order to foster the ability to create new value through technology and enable democratic steering in direction of technology development.

### *3.3. Triple-loop model of Engineering Design Process in NGTE*

As the results of the above survey have shown, there were issues regarding Japanese students did not have sufficient learning experiences to explore principles and mechanisms of technologies, and they could not apply design process to their technological innovation and governance. To address these issues, we proposed the Triple Loop Model of Engineering Design Process. This is shown in Figure 3. 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 utilize various methods such as survey, interviews, or fieldwork and analyse various materials and data in order to identify problems, set tasks, and clarify user's 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.

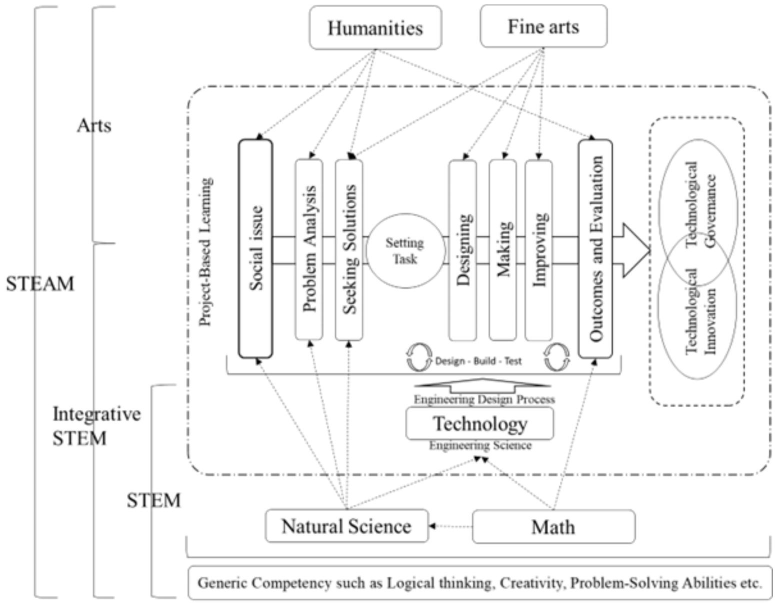
*Figure 3.*
*The Triple Loop Model of engineering design process in NGTE*




### *3.4. A Learning Model of STEAM Education in NGTE*

Essentially, technology and engineering play an important role in bridging between natural science and society/culture through design process. Therefore, in the context of STEAM education, technology and engineering literacy has 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 artifacts and non-technological outcomes. In NGTE, we focused on the former, and have envisioned a practical model of STEAM education that centred engineering-based problem-solving through transdisciplinary learning across all subjects. This learning model can be summarised in Figure 4. This learning model specifically focuses on setting up learning activities for creating technological artifacts such as useful products or systems that may be able to solve authentic problem 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.

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




## 4. CONCLUSION AND FUTURE TASKS

In this paper, we presented an overview of the status of technology education in Japan and introduced the proposed framework for new technology and engineering education by JSTE. As a result, we showed present status of Japanese students as they have a positive perception of "Technology" classes, however, there is a lack of sufficient learning activities that involve exploring technology, and design problem-solving is not adequately linked to the abilities for technological innovation and governance. In the 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 engineering design process, the connections between physical and cyber technologies in that scope., and the learning model of STEAM education that centred engineering design process with various connections among all subject area. 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.

Finally, as all the documents we introduced in this paper are written in Japanese, we hope that through this paper, the NGTE will be made known to technology and engineering educators in other countries. And we are grateful to members of JSTE who took part in the project for development of the NGTE.

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