Proceedings of the International Conference on Education, Vol. 11, Issue 1, 2025, pp.200-212

ISSN 2424-6700 online
DOI: https://doi.org/10.17501/24246700.2025.11116

FRAMEWORK ON CRITICAL THINKING IN THE TECHNOLOGICAL ASSESSMENT AND UTILIZATION ON EDUCATION FOR CITIZENS

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Abstract: The development of competencies has been emphasized globally, with critical thinking increasingly recognized as a key competency. The importance of it has been discussed in Japan, taking up such issues in judgment of technology assessment and control as the nuclear power plant accident. Such risk literacy questions the educational literacy for the use of the scientific and technological systems, and is considered to be an important contemporary issue concerning technological assessment and utilization handled in technology education. This study was extracted the characteristics of thinking included in the critical thinking process and analyzed the teaching contents for technological assessment and utilization and use based on the critical thinking processes. Using perspectives proposed by Ennis and Kusumi, this study extracted elements of critical thinking processes found within these contents and organized the thinking process in the teaching contents for technological assessment and utilization from the viewpoint of critical thinking processes. The results showed that the critical thinking processes were characterized the thinking to focus the discussion, to examine the information source as a premise for inference, to make inductive, deductive, and value judgments based on multiple facts and grounds and to derive the conclusion of the discussion from the process so far. Furthermore, it was suggested that it's important to teach decision-making based on the critical thinking process, combining forward thinking and reflective thinking for fostering the competencies of technological assessment and utilization. This study targets the important theme of how to deal with the technology of installing and operating artifacts such as the nuclear power plant accidents. It also shows significance that structurally demonstrates the critical thinking necessary for each citizen to assess and utilize technology in a future society where technology continues to develop by leaps and bounds.

Keywords: critical thinking, competences of technological assessment and utilization, thinking processes, technology literacy, decision-making, curriculum design

Introduction

The development of competencies is a priority in many countries. Critical thinking is positioned as one of the leading competencies. In Japan, the importance of critical thinking has been discussed in various contexts, such as the nuclear power plant accident. In addition, risk literacy questions the literacy of using scientific and technological systems and is considered an important current issue related to technology assessment and utilization in technology education.

In recent years, there has been a demand for the development of human resources who can solve social issues by utilizing cutting-edge technologies such as Data × AI technology. In response to the introduction of technology, it is necessary to focus on the “light” and the “shadow,” and to cultivate the literacy to make decisions based on the risks. While the advent and development of technology has made our lives richer, it is also true that it comes alongside a variety of risks, such as safety and environmental impact. The theme of “technological assessment and utilization” has been discussed for

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many years in pedagogical research on how to foster the competencies to appropriately assess and utilize technology. In this age of rapid technological development, the competencies of technological assessment and utilization are the important literacy required of each citizen and how to foster these competencies is a significant theme in pedagogy. In the United States, discussions have been ongoing since the 1980s regarding the scientific and technological literacy necessary for all Americans (AAAS 1989) , and ITEA/ITEEA, which form the core of technology education, shows the standards and contents. Based on these background, the importance of fostering technical literacy has also gained attention in Japan, and the cultivation of abilities and attitudes for technological assessment and utilization has begun to be emphasized in the curriculum. However, strategies for systematically developing the competencies of technological assessment and utilization have not yet been clarified.

Previous research analyzed the characteristics of teaching contents in Japanese technology education from the perspective of critical thinking by Ennis(1987), Fascione(1990), Halpern(2007), Sternberg(1986), Kusumi(2018), etc. By the analysis based on teacher survey, it was determined that technology assessment and utilization required higher-order thinking, which combines and puts to work forward and backward thinking, knowledge, and methods (Obayashi and Ohtani, 2023a). Also, prior research suggested that the development of competencies in technology assessment and utilization comprises three processes; thus, it is critical to develop appropriate teaching methods appropriate for each process to cultivate technology assessment and utilization competencies (Obayashi and Ohtani, 2022). Based on these results, the previous study was analyzed the structural characteristics of critical thinking in the teaching contents for technological assessment and utilization under the comparison between science and social studies. The previous study's result was suggested that regarding integrated thinking, all subjects were assessed as having a high need in common, and the fact that science and social studies involve reasoning and judgmental thinking centered on concept acquisition in integrated thinking, whereas technology involves thinking through decision-making was extracted as a subject-specific characteristic (Obayashi and Ohtani, 2023b). Furthermore, it was founded that the teaching contents related to the competencies of technological assessment and utilization were characterized the critical thinking structure that included high-standard thinking that emphasized decision-making unique to technology education, in which the knowledge and methods were combined and put to work while supporting the ability to judge things calmly of science and the ability from multiple perspectives about the relationship between events of social studies (Obayashi and Ohtani, 2023c).

On the other hand, there has been little study done concerning teaching design for developing the competencies of technological assessment and utilization based on these critical thinking structures. Therefore, by targeting the thinking elements indicated in the cognitive processes for exercising critical thinking (critical thinking processes) and linking them to the teaching contents for technological assessment and utilization, it can be possible to bridge the gap between theoretical frameworks and practical application.

Then, to practical application a theoretical framework, this study was extracted the characteristics of thinking included in the critical thinking processes and organized the characteristics of thinking in the teaching contents related to the technological assessment and utilization presented in the curriculum.

Methods

How to perceive the technological assessment and utilization in this study?

In this study, the viewpoint of the technological assessment and utilization is based on the Wisdom of Science and Technology Report, which comprehensively describes the state of technology in relation to science, mathematics, and information, based on recent developments in science and technology. This report is based on the concept of scientific and technological literacy proposed by the All American Association for the Advancement of Science, which is a concept that all Americans should acquire (All American Association for the Advancement of Science, 1990). In this report, it is explained that design (Design) is important in the development of technology, that various methods are assessed to achieve objectives under constraints, that control and management of technology are necessary in the use of technology after its introduction, and that the introduction of these technologies should be preceded and followed by an assessment of their impact on technology. In addition, it is shown that control (Control) and management (Management) of the technology are necessary for the use of the technology after its introduction, and that technology assessment (Assessment) its impact in advance is important for the introduction of these technologies.

In a previous study, Obayashi and Ohtani (2022) indicated that the “technological assessment” is to assess comprehensively the role and impact of technology, and the "utilization of technology” is also to select, management and use based on its role and impact, and improve and apply the technology based on new ideas. Among these, the technological design addresses the elements of technological improvement and application. Furthermore, the elements of Assessment, Control, Management, and Design correspond to Assessment, Selection, Management Use, Improvement, and Application, respectively, and are positioned in the Japanese curriculum (Obayashi and Ohtani, 2025). Through an analysis of the thinking processes in relevant teaching contents based on these classifications, it is considered possible to propose a framework for applying the perspectives required of citizens in technological assessment and utilization to teaching practice.

In this study, the technological assessment and utilization were discussed from the viewpoints of Assessment, Control (Selection), Management Use, Improvement, and Application.

How to perceive the critical thinking process in this study?

The perception of critical thinking includes the perception that each citizen critically examines various types of information and makes judgments. This kind of critical thinking is considered as a concept that involves extensive thinking, and various ways of understanding the structure of the thinking process have been discussed.

In this study, the contents of thinking in the critical thinking processes were extracted by referring to Kusumi's classification (Kusumi, 2018) which organizes a wide range of ways of perceiving critical thinking based on the status of existing research on critical thinking (Ennis 1987), in connection with previous our studies.

How to analyze the critical thinking process in the teaching contents for technological assessment and utilization?

Curriculum development in Japan is regulated in the Courses of Study, which are set by the Ministry of Education, Culture, Sports, Science and Technology once every 10 years. Each school develops instruction based on the Courses of Study. These are standards for organizing the curriculum and are established to ensure that students receive a certain level of education no matter which region of the country they attend school in. Since the Courses of Study are structured based on goals for the development of abilities and attitudes, analysis of this material as a target may reveal the characteristics of thinking required for the development of competencies.

The content of the Courses of Study currently in place was revised in 2017. This revision reflected global trends in developing key competencies and reorganized subject objectives into three main pillars: acquiring knowledge and skills, fostering thinking, judgment, and expression, and nurturing motivation and character. Each subject's goals were structured around these pillars, emphasizing the importance of using its unique “perspectives and ways of thinking,” which form the core of meaningful learning.

Japanese technology education includes four technology topics ―materials and processing, biological growth, energy conversion, and information technology― over three years, and consists of three main learning items in each topic. The first item, "Technologies that support life and society," focuses on understanding existing technologies, including their social roles, safety, and underlying principles. The second item, "Problem Solving through Technology," involves identifying and addressing real-life issues through students’ own thinking and problem-solving approaches. The third item, "Social Development and Technology," encourages students to consider new technologies for improving daily life and achieving sustainability, with attention to technological assessment, control (selection), management use, improvement, and application.

In the content of Japanese technology education mentioned above, the competencies of technological assessment and utilization are to be developed with emphasis, especially in the third learning item. Then, this study targeted the teaching contents of technological assessment and utilization in the third learning item “Social Development and Technology” in the Courses of Study and it’s Commentary, and organized the thinking process in the teaching contents for technological assessment and utilization from the viewpoint of critical thinking processes.

Results and Discussion

Thinking contents in critical thinking processes

Using the four elements related to critical thinking processes shown in Table 1 as a starting point, this chapter extracted the characteristics of thinking in previous studies related to critical thinking processes.

Category 1 is the thinking process regarding “Clarity”. Kusumi sees it as including focusing on and organizing issues and points of contention, identifying the parties' claims and supporting evidence (reasons), analyzing the structure of logic (evidence and claims), etc., and asking questions for

clarification. Ennis also sees the content of thinking as including focusing on the issue, analyzing the argument, and asking questions. From these, it can be taken that the thinking process of clarification includes thinking to focus the discussion through analyzing the issues and asking questions. Then, this process can be perceived as a thinking process to clarify the discussion point.

Table 1: Perspectives interpreted based on the critical thinking processes and the extracted content of thinking in each process

Classifi-cation	**Critical Thinking Process**	**Consideration of the thinking content included in the thinking process**	**Perspectives interpreted based on the Thinking Process**	**Extracted thinking content**
1	Clarity	Kusumi sees it as including focusing on and organizing issues and points of contention, identifying the parties' claims and supporting evidence (reasons), analyzing the structure of logic (evidence and claims), etc., and asking questions for clarification. Ennis also sees the content of thinking as including focusing on the issue, analyzing the argument, and asking questions. From these, it can be taken that the thinking process of clarification includes Thinking to clarify the discussion point.	Perspective to clarify the discussion point	Thinking to clarify the discussion point
2	Examination of the Basis of Inference	Kusumi sees it as including clarifying hidden assumptions about clarified information, examining whether the information is based on reliable evidence, and evaluating scientific facts and results. Ennis also sees it as including judging the reliability of information sources and making observations based on the statements of others, observations, and one's own previous inferences. From these facts, it can be taken that the thought process of examining the foundation of	Perspective of examining information sources as premises of inferences	Thinking to examine the information source as a premise for inference

		inference includes the thought of examining the information sources that are the premise of inference through judgments of objectivity and reliability.		
3	Inference	Kusumi sees it as including induction, deduction, value judgments, etc., and drawing correct conclusions from the information sources on which the reasoning is based. Ennis also sees it as including judging the process by which conclusions are drawn, generalizing hypotheses and making inferences, and making value judgments. From these, the thinking process of inference can be taken to include judgments based on multiple facts and evidence through induction, deduction, and value judgments in order to reach the conclusion of an argument.	Perspectives of induction, deduction, and value judgment based on multiple facts and grounds	Thinking to make inductive, deductive, and value judgments based on multiple facts and grounds
4	Decision about Action	Kusumi considers that it includes drawing conclusions based on the process so far, making action decisions based on the situation, and solving problems. Ennis also considers that it includes making rational decisions about what to do through interactions with others, examining errors, and so on. From the above, the thinking process of action decision-making can be considered to include thinking to derive the conclusion of an argument from the previous process.	Perspective to derive the conclusion of discussion from the previous process	Thinking to derive the conclusion of the discussion from the process so far

Category 2 is the thinking process regarding “Examination of the Basis of Inference”.Kusumi sees it as including clarifying hidden assumptions about clarified information, examining whether the information is based on reliable evidence, and evaluating scientific facts and results. Ennis also sees it as including judging the reliability of information sources and making observations based on the

statements of others, observations, and one's own previous inferences. From these facts, it can be taken that the thinking process of examining the foundation of inference includes the thought of examining the information sources that are the premise of inference through judgments of objectivity and reliability.

Category 3 is the thinking process regarding “Inference”. Kusumi sees it as including induction, deduction, value judgments, etc., and drawing correct conclusions from the information sources on which the reasoning is based. Ennis also sees it as including judging the process by which conclusions are drawn, generalizing hypotheses and making inferences, and making value judgments. From these, the thinking process of inference can be taken to include judgments based on multiple facts and evidence through induction, deduction, and value judgments in order to reach the conclusion of an argument.

Category 4 is the thinking process regarding ““Decision about Action”. Kusumi considers that it includes drawing conclusions based on the process so far, making action decisions based on the situation, and solving problems. Ennis also considers that it includes making rational decisions about what to do through interactions with others, examining errors, and so on. From the above, the thinking process of action decision-making can be considered to include thinking to derive the conclusion of an argument from the previous process.

As described above, the critical thinking processes consisting of Clarity, Examination of the Basis of Inference, Inference, and Decision about Action were found to include thinking to focus the discussion, to examine the information source as a premise for inference, to make inductive, deductive, and value judgments based on multiple facts and grounds, and to derive the conclusion of the discussion from the process so far.

Characteristics of the critical thinking processes in the teaching contents for technological assessment and utilization

The previous section was extracted perspectives interpreted based on the critical thinking processes and the extracted content of thinking in each process. Then this chapter analyzed the teaching contents of technological assessment and utilization in the third learning item “Social Development and Technology” in the Courses of Study Commentary, and organized the thinking process in the teaching contents for technological assessment and utilization from the viewpoint of critical thinking process.

Table 2 showed that the thinking contents in the critical thinking processes in the teaching content for technological assessment. In the Courses of Study, the teaching content for technological assessment is positioned as for technological assessment to build a better life and a sustainable society. And it's commentary described “learning activities to organize the advantages and problems of new energy technologies being researched and developed, evaluation of the environmental impact, performance, and price as well as the production, transportation, sales, use, disposal, and reuse of equipment at each stage, and consideration of environmentally friendly lifestyles are exemplified", as an example activity regarding the study of energy technologies. In this learning activity, the process of thinking to clarify the discussion point involves thinking to clarify the argument "To consider the advantages and

problems of new energy conversion technologies that are being researched and developed". In the second process ―Thinking to examine the information source as a premise for inference―, students review sources of information on the performance and price of modern electrical equipment, the environmental impact of modern electrical equipment at all stages of manufacture, transport, sale, use, disposal, and reuse, and environmentally friendly living. Based on this basis, the third process involves thinking to judge the excellence and problems of the new energy conversion technologies being researched and developed. In this process, students reason based on the social and natural science aspects of technology, and determine the advantages and problems of the technological system. In this process, while utilizing the thinking nurtured in science and social studies, as seen in previous studies, the students must also combine knowledge and methods to make decisions that are unique to technology education. In the fourth process ― thinking to derive the conclusion of the discussion from the process so far―, students organize the advantages and problems of new energy conversion technologies that are being researched and developed, and draw conclusions from the discussion, in other words, the decision make to technological assessment. As described above, the teaching content for technological assessment can be expected to include thinking in line with the critical thinking processes in assessing technology and making decisions.

Table 2: Thinking contents in the critical thinking processes in the teaching content for technological assessment

Teaching Content for Technological Assessment	**Thinking Content in the Critical Thinking Process**			
	Clarity	Examination of the Basis of Inference	Inference	Decision about Action
	Thinking to clarify the discussion point	Thinking to examine the information source as a premise for inference	Thinking to make inductive, deductive, and value judgments based on multiple facts and grounds	Thinking to derive the conclusion of the discussion from the process so far
Technological Assessment	To consider the advantages and problems of new energy conversion technologies that are being researched and developed	Review sources of information on the performance and price of modern electrical equipment, the environmental impact of modern electrical equipment at all stages of manufacture, transport, sale, use, disposal, and reuse, and environmentally friendly living.	To judge the excellence and problems of the new energy conversion technologies being researched and developed	Organize the advantages and problems of new energy conversion technologies that are being researched and developed, and draw conclusions from the discussion.

Then, the teaching contents and critical thinking processes related to the utilization of technology based on technological assessment. Table 3 showed that the thinking contents in the critical thinking processes in the teaching content for utilization of technology. In the Courses of Study, the teaching contents for utilization of technology are positioned as for thinking about appropriate technological control, management and use, and generating ideas for new technological improvement and application. And it's commentary described “learning activities to discuss appropriate technological control, management and use from the viewpoint to build a better life and a sustainable society, and to make decisions, to put together a proposal about the future prospect of technology from the standpoints of both users and developers”, as the example activities regarding the study of energy technologies. Although the details of these studies differ in terms of control (selection), management use, improvement, and application, they all involve activities that consider themes related to the use of technology. In these learning activities, as first process, students clarify the discussion point that "consider about control / management and use of appropriate technology, or new ideas the improvement /application of appropriate technology as a future vision of technology from the standpoint of both users and developers". In the second process, students review sources of information on the advantages of new energy conversion technologies that are being researched and developed and on the problems of new energy conversion technologies that are being researched and developed. Based on this basis, the third process involves thinking to make decisions on how to control/management/improvement /application of appropriate technologies for the future, both from the user's and the developer's standpoints. As with the technological assessment, it is important to work higher order thinking in this process. In the fourth process, students make decisions about how to control/management/ improvement/application appropriate technologies for the future, and draw conclusions from the discussions by presenting or summarizing recommendations, in other words, the decision make concerning utilization of technology.

As described above, it can be considered that the teaching contents for technological assessment and utilization include thinking in line with critical thinking processes for making decisions regarding the technological assessment and utilization. Therefore, it was suggested that it's important to teach decision-making based on the critical thinking process, combining forward thinking and reflective thinking for fostering the competencies of technological assessment and utilization.

Table 3: Thinking contents in the critical thinking processes in the teaching content for utilization of technology

Teaching Contents for Technological Utilization	**Thinking Content in the Critical Thinking Process**			
	Clarification	Examination of the Foundations of Reasoning	Inference	Action Decision

	Thinking to clarify the discussion point	Thinking to examine the information source as a premise for inference	Thinking to make inductive, deductive, and value judgments based on multiple facts and grounds	Thinking to derive the conclusion of the discussion from the process so far
Technological Control (Selection)	To consider the control of appropriate technology as a future vision of technology from the standpoint of both users and developers	Review sources of information on the advantages of new energy conversion technologies that are being researched and developed and on the problems of new energy conversion technologies that are being researched and developed	To make decisions on how to control appropriate technologies for the future, both from the user's and the developer's standpoints.	Make decisions about how to control appropriate technologies for the future, and draw conclusions from the discussions by presenting or summarizing recommendations
Technological Management Use	To consider the management and use of appropriate technology as a future vision of technology from the standpoint of both users and developers		To make decisions on how to manage and use appropriate technologies for the future, both from the user's and the developer's standpoints.	Make decisions about how to manage and use appropriate technologies for the future, and draw conclusions from the discussions by presenting or summarizing recommendations
Technological Improvement	To consider about new ideas the improvement of appropriate technology as a future vision of		To make decisions on how to improve appropriate technologies for the future, both from the user's	Make decisions about how to improve appropriate technologies for the future, and draw conclusions

	technology from the standpoint of both users and developers	and the developer's standpoints.	from the discussions by presenting or summarizing recommendations
Technological Application	To consider the applications of appropriate technology as a future vision of technology from the standpoint of both users and developers	To make decisions on how to applicate appropriate technologies for the future, both from the user's and the developer's standpoints.	Make decisions about how to applicate appropriate technologies for the future, and draw conclusions from the discussions by presenting or summarizing recommendations

Conclusion

This study was extracted the characteristics of thinking included in the critical thinking process and analyzed the teaching contents for technological assessment and utilization and use based on the critical thinking processes. The results showed that the critical thinking processes were characterized the thinking to focus the discussion, to examine the information source as a premise for inference, to make inductive, deductive, and value judgments based on multiple facts and grounds and to derive the conclusion of the discussion from the process so far. Also, it can be considered that the teaching contents for technological assessment and utilization include thinking in line with critical thinking processes for making decisions regarding the technological assessment and utilization. Furthermore, it was suggested that it's important to teach decision-making based on the critical thinking process, combining forward thinking and reflective thinking for fostering the competencies of technological assessment and utilization. In applying this framework to actual teaching practice, these processes could be applied to scientific and social aspects of technology and to decision-making situations based on these aspects. On the other hand, since this study and previous studies have focused on the teaching contents in curriculum, teaching design is required to fill in the gaps in the current situation, such as the extent to which students are actually able to think and which types of thinking they have difficulty with.

A further study of learning designs for technological assessment and utilization based on the critical thinking processes organized in this study should be conducted. In order to apply the characteristics of thinking on the technological assessment and utilization in line with the critical thinking processes extracted in this study to actual instruction, a further study will examine teaching designs for junior

high school students and verify their effectiveness through teaching practice. Specifically, it will conduct teaching practices using different teaching methods based on the critical thinking processes, analyze the differences in effectiveness, and propose effective teaching methods and rational methods for the technological assessment and utilization to demonstrate critical thinking in a well-balanced manner and to evaluate learning.

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