Chapter 8
The Study of Elementary Science: Aspects of Excellence and Equality

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Abstract This chapter discusses the 2017 revisions to the science course of study against historical and contemporary debates in Japan. Historically, two points have attracted debate: (1) determining the objectives of the science courses, and how the educational content should be selected, prioritised, and ordered—the scope and sequence of curriculum; and (2) determining for whom the educational content is appropriate—the question of its relation to indigenous knowledge. Analysing from the former point of view will help to clarify the quality of excellence that has been pursued within science education in Japan. The latter will help to evaluate whether excellence is equally guaranteed to all children from a curriculum perspective. The background of these debates is discussed, before examining the course of study in relation to these historic and domestic debates, alongside newer global debates of key competencies. The discussion is illustrated using examples from the new course of study in order to keep the discussion grounded in school practice. The progressive agenda for Japan's science course of study is evaluated on its capacity to simultaneously ensure excellence and equality. This will provide suggestions that will facilitate science education reform for a knowledge-based society.

Keyword Science Education · Excellence and equality · Indigenous science · Universalism and multiculturalism

Unprecedented changes are occurring in Japan. There is continued scientific and technological development, including in artificial intelligence research, with proposals such as the 'Society 5.0' concept, symbolised by a new type of knowledge society. In addition, the country faces trials consequential of the indeterminate Covid-19 virus. As for education, there are two possibilities: whilst its general path is determined by the characteristics of contemporary society and the historical era, it is also a participant in determining the fundamentals of society and the age (Nakauchi, 1988). In

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Japanese society today, which itself stands at a turning point, basic principles of education are also faced with questions regarding a dramatic shift to accommodate these social and historic changes.

As Japan explores new principles of educational innovation, one important idea is the simultaneous pursuit of 'quality' and 'equality'. An example is the Science Council of Japan's 2010 report on policy proposals for education in 2030. This report, titled *Prospects for the Field of Pedagogy*, states the following: 'In today's globalising world, excellent educational quality is needed to be globally competitive. At the same time, educational reform is urgently needed to address the various risks that stem from rapid societal changes; guaranteeing the right to learn in order to help prevent social stratification and creating equal educational opportunities are also crucial' (Science Council of Japan, 2010: 1).

In addition, the pillars of the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015 include the objective to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all'. In a knowledge-based society, the opportunity to learn marks the line between inclusion and exclusion. To ensure meaningful lives, society must guarantee a fair and equal opportunity for all children to enjoy high-quality education. This is an issue of global importance.

Looking back to past debates, there is a need for more than just the systematic pursuit of excellence and a guarantee of equal education (Okada, 2013). Cultural studies of the 1980s revealed that certain views and ideas about gender, sexuality, race and ethnicity, identity are woven into various cultures, knowledge bases, and institutions, that require a discussion of a 'politics of differences' (Koyasu, 2009). According to this perspective, the knowledge taught in schools is not value-neutral, adding complexity to the problems of quality and equality of education. Even quality educational content taught in the classroom may deprive individual children of educational opportunity if the content denigrates the culture and values of that particular child. This is an issue of fairness that calls for careful examination of educational content. A particular issue in this process is whether equal, shared, standard educational content can achieve both universality and diversity at the same time (Tanaka, 1994). What is demanded, then, is not these self-contradictory objectives of universality and cultural diversity in educational content. Instead, within each specific culture, there needs to be a re-questioning of universality from culturally diverse perspectives, to discover universal educational content that is informed by diversity and diverse perspectives. There must be a guarantee that this content will be delivered fairly and equally to all children.

It should be noted that in many countries, discussions about establishing both excellence and fairness have chiefly concerned the sciences and mathematics. The international focus on science and mathematics education originates from a recognition amongst all developed nations of the roles played by excellence in science in terms of the safety and security of a nation and its people, and efforts to improve living standards and strengthen the country in terms of international competition, etc. However, because fairness does not contribute so directly to these developmental aims, these preoccupations made the simultaneous achievement of excellence and fairness within science and mathematics curricula a perennial issue of importance in many countries, and Japan was, and still is, no exception.

In Japan, the national government's course of study corresponds to standards in other countries. The course of study includes statements regarding the educational objectives and content of each subject ('course') of study, points of special concern for instruction in each subject, etc. This chapter will trace debates and developments regarding excellence and fairness in Japan's science education, chiefly from the perspective of educational content. From this perspective, the 2017 revision of the course of study for science is analysed to clarify its significance and the issues to be resolved. The following section sets out the debate over the educational content of the course of study for science. Section 8.3 examines the theoretical perspectives that underpin the latest (2017) revision of the course of study for science and the practices that emerge from it. Finally, the significance and challenges of them will be discussed in light of the previous discussions featured here.

8.1 Debate Regarding Educational Content in the Course of Study for Science

The curriculum organisation of elementary, middle, and high schools in post-war Japan, as a principle, is conducted in accordance with the course of study determined by the Ministry of Education (MEXT). The course of study lists objectives and content for each subject along with general rules that constitute the fundamental policies for curriculum organisation. Since Japan employs a Ministry-led approval system for school textbooks, the course of study serves as the main textbook-screening standard (Nishioka, 2017). The course of study is the near-national curriculum which regulates the school. The entrance examination system, in which the entrance exam for public universities does not include content outside of the course of study, makes them legally binding even beyond school education.

Historically two points have attracted debate: (1) determining the objectives of the science courses, and how the educational content should be selected, prioritised, and ordered—the scope and sequence of curriculum; and (2) determining for whom the educational content is appropriate. Analysing from the former point of view will help to clarify the quality of excellence that has been pursued in science education in Japan. In addition, the perspective on universality and multiculturalism provided by the latter perspective will help to evaluate whether excellence is equally guaranteed to all children from a curriculum perspective.

8.1.1 The Status of Science and the Selection and Arrangement of Educational Content

The objectives of a science course depend on the character of the courses and on the selection of educational content. In Japan, unlike in other countries, there are two close-related concepts that are often both translated to ‘science’, namely *rika* and *kagaku*. *Rika* is considered to be a subject that does not intend to instruct in the natural sciences. Rather, its objectives are to understand basic natural phenomena and to foster an appreciation for nature (Itakura, 2009: Kosano, 2007; Mori, 2017). The science courses we are discussing in this section sit under the umbrella of *rika* science. It is this perspective on science, which is emphasised by the course of study, oriented towards the mastery of knowledge about real, visible things, including natural phenomena, through the encouragement of observation and experimentation. The objectives here are to master scientific inquiry methods and develop the attitude needed for such pursuits.

The historical background to the emphasis of Japanese education on the understanding of natural phenomena is the postwar *seikatsu tangen gakushu*, an interdisciplinary and experiential course based on students’ life which literally translates to ‘unit for studies on life’. *Seikatsu tangen gakushu* roots learning in the lived experience of the child. The course of study published in 1947 said that the content and methods of rika science teaching must be based on the local flora, fauna, weather, and machinery that the children will experience. And through such learning, it set three goals for children to acquire: (1) the ability to see, think, and deal with things scientifically, (2) knowledge of the principles and applications of science, and (3) the attitude to find the truth and create new things (MOE, 1947).

However, many teachers criticised this approach since natural science is more cumulative. They have called for a course with knowledge-based progression. Because *rika* science structured the content of science education around life-related issues, the order of learning did not progress cumulatively, and therefore students were not necessarily using previously learnt material as tools for problem-solving. This was a criticism of the educational content and its arrangement in the course of study.

A representative group with these beliefs is the Association of Science Education (ASE), established in 1954. The ASE is a civic educational research association[1] on education in the school subject of science, mainly composed of school teachers and university researchers in education and natural or applied sciences. Having analysed and investigated the course of study, the ASE has proposed detailed course content and instruction methods that it deems necessary for all children to successfully learn the facts and laws of natural science. The most salient difference between the ASE’s

[1] Civic educational research associations are composed mainly of teachers and educational researchers, generating new knowledge in the practice of education. They cover broad topics and approaches, and have traditions outside and sometimes against government and teachers’ unions. Some associations coalesce into movements.

proposal, compared to the course of study, was its prioritisation of conceptual knowledge, over and above the acquisition of methods of scientific inquiry, learning to appreciate nature, etc.

The ASE was alarmed by the tendency to neglect disciplines in the course of study in the 1950s. For example, in the course of study of that time, teaching materials were selected from everyday life. Examples might include personal items such as windmills, making soap bubbles, or manipulating the wiring of electric lights. In line with *seikatsu tangen gakushu*, they were sequenced and organised from the standpoint of the basics of life and industry. However, ASE argued that, for example, in the study of buoyancy, concepts such as weight, density, and gravity needed to be recognised in an orderly fashion in line with the discipline (Mafune, 1962). Hisao Morikawa of the National Institute for Educational Policy Research advocated a continuation of the position that 'knowledge and content do not matter as long as they are appropriate materials for enquiry' (Morikawa, 1969: 10). This debate has continued for over half a century, with the course of study still largely aligned to *rika* science.

The differences between the ASE and the course of study appear in their respective content selections and designs. The analysis below focuses on educational content and methods of using materials to teach concepts pertaining to transformations between the three states of nature—solid, liquid, and gas. In the course of study for fourth grade science, 'The form of water changes into vapour or ice depending on temperature. When water becomes ice, its volume increases' (MEXT, 2008: 41). The main objective is to grasp the three-state changes of water, and learning proceeds using materials concerning natural phenomena with which children are familiar, such as fog, the evaporation of water puddles, etc. Here, activities are performed, including data collection, making graphs, and reporting one's thoughts using illustrations and pictures.

In the corresponding educational content set forth by the ASE, 'three states exist according to temperature: solid, liquid, and gas' (Kosano, 2007: 93). Children are to perform experiments involving changing the temperature of ethanol to confirm that both ethanol and water evaporate and solidify. On that foundation, the students' understanding is expanded with the knowledge that changes in temperature can cause liquids other than water, such as solids like tin and salt, and gases like butane, to solidify or become gaseous. Students thus learn educational content related to laws that have a wide range of applications, as all things change state according to temperature. In other words, fundamental natural science content is included. The objective is for children to acquire a 'lens' through which they can observe the physical world.

Comparing the ASE and the course of study, the latter takes up the natural phenomenon of water evaporation, emphasising knowledge, experimentation, and observation using individual materials that the eye can see. Through these, the main focus is on methods of inquiry (collecting data, etc.) and on fostering certain attitudes. Although the ASE also employs the medium of experimentation using familiar objects, the backdrop is individual phenomena that are considered to be part of *kagaku* science education, pivoting on the formation of universal laws and concepts.

Masaki Kosano of the ASE criticises the course of study approach as follows: ‘In Japan’s science (*rika*) education, the objective is to teach “science (*rika*) which can be used in daily life”—that is, something with no connection to future science (*kagaku*). This education is an attempt to teach “conceptual emotions,” that is, a “love of science”. The “way of thinking” and “methods” aimed for have nothing to do with actual scientific content. The result is that students learn contents that are actually “distant” from those of natural science’ (Kosano, 2009: 103). According to the ASE, practices based on the course of study pay insufficient heed to the systematic academic study of educational content. The course of study of the natural states limits discussions of the three states to water and only offers materials pertaining to water-related changes. These practical methods have been denounced and ‘removed’ from natural science (*kagaku*) academic content on the premise that their end result is short-sighted learning with no connection to the formation of concepts that would actually lead to a deeper appreciation for nature.

In contrast, the main axis for the ASE is the formation of systematically related concepts. Returning to the example of the three natural states, the abovementioned educational content is studied, partly as preparation for the study of states of matter and molecular motion in junior high school. Taking a balloon filled with liquid alcohol and a balloon filled with water and submerging each in 90 °C water, students compare the relative expansion of each balloon. During this exercise, students learn that liquids other than water can boil and that different types of matter have different boiling points. Students learn about the transformation of states by melting a solid, such as tin or salt, solidifying a liquid like mercury, sublimating dry ice, etc.

The ASE makes a clear distinction between educational goals and educational content and subject matter and tools (Mafune, 1962). The ASE thus proceeds with systematic academics, arranged in a sequence that considers students’ cognitive abilities, so that all students may grasp these basic concepts. This approach systematically organises an abundant variety of subject matter content, allowing students to experience and acquire a scientific worldview that is common to contemporary natural science. A secondary effect is that scientific attitudes and methods are intricately linked with these experiences.

In this way, the ASE emphasises the mastery of universal core scientific concepts, whilst students learn about the fruits of modern science. In accordance with the orientation of each course, educational content and materials are systematically arranged to accomplish these objectives. In the course of study, the first priority is understanding familiar objects and phenomena, with the objective of acquiring scientific methods and a scientific attitude. The result entails the risk that it may fail to make important connections with core universal natural science concepts, thus creating an accumulation of superficial, miscellaneous knowledge about individual phenomena departing from children’s lives.

8.1.2 *The Educational Content of* **Rika** *Science and Diversity Aspects*

From the viewpoint of critical pedagogy[2] findings in Japan and overseas, a question arises regarding educational content, such as in the course of study, which is considered common official knowledge: whose cultural values are given top priority? (Apple, 2000). The natural science content taken up either in *rika* or *kagaku* science are thought, as opposed to literature or social science content, are thought to be 'value-neutral' (Kosano, 2018).

On this point, Masataka Ogawa's idea of 'science as a foreign culture' is suggestive. Ogawa, a proponent of 'pluralistic science education', considers science (*kagaku*) from three dimensions. First, there is (a) 'individual science', with understanding on an individual level. Next, there is (b) 'indigenous science', with understanding on a village community level. Finally, there is (c) 'Western science', with understanding based on the beliefs and norms shared by a group, namely the community of scientists (Ogawa, 1998). For example, (a) a child explains rainfall as 'the sky is crying'; (b) another child from Nepal says that the gods are breaking water-filled vessels; and (c) a child explains how water and ice gather and form clouds, with the water and ice eventually falling to earth due to gravity. These examples demonstrate that different people may conceive the same natural phenomenon in different ways. At this point, there is a division in science, and Ogawa says that individuals use this multilayered world of science as they go about their daily lives.

At first glance, it may seem that 'indigenous science' is equivalent to folktales and myths, but indigenous science is not necessarily only a product of the imagination. The 'Oriental science' of China and the Yupik people of Alaska are examples of cultures where there is a different systematisation of knowledge concerning climate and seasonal changes (Kawagley, 1998). When the village community hunts and gathers, stories are passed on at local sites. Whilst there is no guarantee of validity or objectivity, these stories contribute to the preservation of ecosystems. In this way, science (*kagaku*) is seen to have multiple origins and practices; each society and culture possesses a unique (indigenous) science, functioning to maintain that society and/or culture.

Ogawa uses this perspective to analyse *rika* science described in the course of study. He points out that this does not present the science (*kagaku*) that is considered in many countries to be the sole universal science (i.e., Western science); instead, *rika* presents a complex science that is actually (and implicitly) a delicate balance between indigenous and Western science (Ogawa, 2006). For instance, Ogawa uses the dissection of a frog as an example. From the perspective of Western science, dissecting a frog is an opportunity to see and learn about the inside of an organism's body. In Japanese schools, in addition to this, the frog is buried after the dissection

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[2] Critical pedagogy is defined as broadly seeking to expose how relations of power and inequality, (social, cultural, economic), in their myriad forms combinations, and complexities, are manifest and are challenged in the formal and informal education of children and adults (Apple et al., 2009: 3).

exercise is completed, and a ceremony is performed, demonstrating an animistic value system (here, Japanese views on life and death). Ogawa argues that there is therefore a coexistence of Western and indigenous science (Ogawa, 2006).

The course of study takes the position that science (*kagaku*) is a culture that relies on Western science: 'Science (*kagaku*) can be thought of as a culture, established over a long period of time by humans. The fundamental condition which makes science distinct from other cultures is considered to be its verifiability, reproducibility, objectivity, etc.' (ibid.). In other words, in the course of study, Western science is seen as the one and only science, as it is not oriented towards local indigenous science, which may lack reproducibility and objectivity. The result is that the course of study discards much of the indigenous science that is inherent to students' society and culture, creating the risk of functioning as a cultural assimilation mechanism, whereby the local culture is assimilated into this hybrid type of science (*kagaku*).

This problem of indigenous science is not always overlooked in science (*kagaku*) education. The Polar Method Association (極地方式研究会 *Kyokuchi Hoshiki Kenkyukai*) was formed by members of the existing ASE in 1971. This new group emphasised the importance of introducing children to universal concepts through the study of locally indigenous organisms in the classroom (Polar Method Association 1971). Take the newt for example. In Japan, there are newts with different patterns and tails, such as the Tokyo newt, the Niigata newt, and the Kyoto newt. In the method advocated by the Polar Method Association, children bring examples of these local creatures to the classroom and introduce them. This is intended to 'shake' the children's concept of newts and lead to a deeper understanding of newts. It is to be commended that the Polar Method Association has attempted to make people look at the environment around them and connect the concept of universality by taking up endemic, and thus indigenous, cases in this way. However, this only positions the indigenous cases as a means of reaching a deeper understanding of universal concepts and does not necessarily mean that the value of the indigenous cases is evaluated or that the value of the universal cases is re-examined through local knowledge. In this respect, they can be also considered fragmentary additions to the dominant culture.

Useful as a reference on this point is the idea of Clinical Epistemology, proposed by the late philosopher Yujiro Nakamura. First, Nakamura states that the three characteristics of modern science—universality, logicality, objectivity—also serve as tools for its proponents to convince others of its value, even to the exclusion of other knowledges. With this knowledge, Nakamura (1992) argues, phenomena of the living world can be extracted, 'materialised', and divided into parts, thus enabling a detailed investigation of each part of the natural world. Nevertheless, it is rare to find any causal relationship which is singular, even for simple natural phenomena. phenomena of the living world are complex systems with, at best, vast networks of causal relationships. For example, the movement of a falling ball is influenced by a variety of factors in addition to gravity and air resistance. Consideration must be given to the individual time, place, and other circumstances of each phenomenon and to their mutual interactions. When examining psychological processes or human experience of an event, the number of factors required for a 'universal, logical, and objective' analysis become unrealistic. In this way, Nakamura contrasts Clinical Epistemology, incorporating knowledge of the specific, with scientific knowledge.

Western science advocates generality and universality, and has objectives related to factual knowledge, with wide-ranging predictions and applications. Western science does not readily provide appropriate responses for individual cultures, traditions, and problem states. Instead, dynamic interactions between indigenous and scientific knowledge, as described by Ogawa, enable solutions to a variety of problems, from the local site to the international level. This signifies the acquisition of knowledge that has universality, tempered by its application to multiple different cultures. It is therefore necessary to examine the concepts that are thought to be universal, such as principles and laws, from a multicultural point of view and to identify what is of shared value to culturally and linguistically diverse children, rather than just focusing on the acquisition of these concepts.[3]

'Indigenous knowledge' is found in local cultures within Japan. Generally, however, the term 'multicultural' conjures the image of a culture formed from people of different races and ethnic groups, genders and social classes, sexualities and disabilities. One also sees efforts to question science, hitherto written by men, from the standpoint of women. One example is the position of an American female researcher in primatology, who focuses not on the control of primate groups by aggressive males with territorial behaviour, but instead on the roles of females who cooperate to preserve the stability of their societies (Schiebinger, 1999). In this way, the 'facts' of scientific research, once considered 'universal' using the concepts and methods proposed by men, are undergoing questioning from the cultural and positional perspectives of women. Knowledge systems, then, are being reconfigured, and the detailing of hitherto unknown facts and principles is contributing to existing cultures, thereby further enriching and enhancing these cultures.

If the selection and arrangement of educational content do not reflect the cultures of these diverse groups, then said content shows a biased 'universality', which makes the systematic nature of the depicted academic disciplines seem outmoded. If indigenous science is not sufficiently incorporated into education, then children with foreign relational ties and women may become further marginalised despite being given the chance to participate in formal science courses.

Of course, this does not mean that unconsidered efforts should be made to reflect indigenous science within education courses. For example, in some foreign countries, there are regions where, traditionally, urine is used for medicinal purposes by applying it as a salve for wounds. This is different from the indigenous science discussed above, in that a person who relies on Western science would consider this practice unscientific and would thus consider the practice 'opposed to reason' rather than 'complementary'. Here, then, a cultural confrontation emerges. Moreover, adding this practice to educational courses would invite overgeneralisation and

[3] In this respect, the Polar Method Association was oriented towards teaching a science that was more universal than the laws in the name of a high level science. For example, instead of teaching Hooke's Law, which focused on springs, the Polar Method Association focused on the fact that everything is elastic (Takahashi & Hosoya, 1974).

curriculum ‘bloating’. Such points remain problematic when considering policies for reflecting a multicultural perspective within educational course content.

To summarise, in science (*rika*) education, the objective is to achieve both fairness and excellence, and doing so requires the accomplishment of the following three points regarding educational content.

1. Content should be selected and arranged so that it has a high degree of universality.
2. Debate involving multicultural perspectives is necessary for the concepts selected in (1), together with careful consideration of details.
3. Content selected must be clarified in terms of its universality, tempered with multicultural aspects, and there must be a guarantee of fairness.

8.2 Theoretical Background for the 2017 Revision of the Course of Study and Concrete Practices

8.2.1 Theoretical Background for the 2017 Revision of the Course of Study

From the beginning of the 2000s, the fostering of general abilities under the rubric of ‘competencies’ has become an international priority in education. The engine behind this shift is the OECD’s Definition and Selection of Competencies (DeSeCo) Project (Matsuo, 2015). These are qualities and abilities beyond the mere mastery of knowledge and techniques. They include the ability to use knowledge and techniques to solve problems.

In Japan, calls for education competencies began in the latter half of the 2000s. The backdrop for such calls included the following. (1) With the development of artificial intelligence and information and communications technologies (ICT), there was a growing demand for highly creative work utilising high-level cognitive functions (economic demand). (2) Due to increasing trans-scientific issues and problems, there was a need for individual citizens to have a rational and critical understanding of decisions made by scientific experts, etc., as well for said citizens to themselves explore optimal solutions (societal and citizen-related demands). (3) The development of various sciences, including the so-called ‘learning sciences’, clarified the role of competencies, such as metacognition, etc., as a means of effective learning (Ishii, 2015; Nishioka, 2016).

Prior to the 2017 revision of the course of study, an Investigative Commission was established with the mission of studying optimal educational objectives and content, as well as assessing said objectives and content, all in the goal of fostering competencies. This Commission had as its objectives (1) the clarification of the structure of required competencies within elementary and secondary education in preparation for said revision, and (2) the clarification of educational methods for realising said structure, with the aim of fostering competencies (MEXT, 2014).

The Commission drew three conclusions regarding competencies. First, there should be an awareness that educational objectives for core competencies must guarantee every individual's right to grow and develop, as well as give them the abilities they need to live and prosper in contemporary society (Nishioka, 2016). Second, the Commission indicated guidelines and instructions for arranging objectives for each educational course, in line with the course of study revision. Specifically, this would be achieved by having students and teachers participate in authentic assessments, with the objective of promoting a deeper understanding of the core concepts of each course, such as, for example, 'What is energy?'. And third, the Commission recommended instruction methods for enabling the comprehensive and contextual use of general skills in addition to core competencies by means of participation, that is, having students and teachers engage in completing authentic tasks. The results of the Investigative Commission informed a more formal report of the Central Council of Education entitled *Improvement of the Courses of Study* (2016).

The aims of the existing (2008) course of study were to develop students' abilities to think, make judgements, and express themselves. These aims did not move far from having students memorise and recall individual and concrete knowledge-related facts. The report thus presented new objectives, whereby academic achievement would encompass the active use of acquired knowledge, so that students would be able to apply their knowledge to specific situations and circumstances (Central Education Council, 2016: 15). The report further proposed a revision of existing learning methods, such that instruction could help students to achieve the academic levels required to actively use and apply their knowledge, with said instruction being based on the perspectives of 'proactive, interactive, and authentic learning', which is often referred to as 'active learning'.

On this foundation, the report laid out educational objectives in preparation for the revision of the course of study. The policies stated therein would foster 'three pillars of competencies', and 'ways of thinking and considering [that are] appropriate for each academic course, etc.' The three pillars under the course of study are for schools to foster the following competencies: (1) mastery of the knowledge and techniques needed for students to ask themselves 'What do I understand now?' and 'What can I do now?'; (2) fostering the ability to think, make judgements, and engage in self-expression, so that students may learn how to actually apply and use what they currently understand and are able to do; and (3) fostering non-cognitive aspects, including students' ability to orient themselves to learning and to an understanding of how they can live meaningful lives, whilst participating in and contributing to their societies and to the world (Central Education Council, 2016: 28–30).

Regarding (3), the emphasis on fostering competencies involves the danger of slighting educational content. To overcome this hurdle, perspectives and ways of thinking are introduced for each course. This indicates that perspectives and ways of thinking may differ due to the unique characteristics of each course; hence, there is a clear statement about what perspectives should be used to observe things and events, and as to what specific styles of thinking are needed for each course. This fostering of competencies in tandem with such perspectives and ways of thinking is designed to stimulate authentic learning in each course, enabling the realisation of proactive, interactive, and authentic learning within the classroom setting.

This report, produced by the same body that oversees the formulation of the course of study, was the main point of reference for the drafting of the 2017 revision of the course of study.

8.2.2 *The Specific Case of* Rika *Science*

Based on this report, the course of study for *rika* science also incorporates policies for using scientific perspectives and ways of thinking that are appropriate for each class type, so as to foster general competencies. In elementary school science, it is stated that 'the aim is to develop the competencies necessary to solve problems related to natural things and phenomena through familiarity with nature, application of scientific perspectives and ways of thinking, and carrying out observation and experimentation with a clear perspective' (MEXT, 2017: 12).

Three abilities are included in the course of study that could be interpreted as competencies for *rika* science.

1. Fundamental techniques for measuring, observing, and experimenting are to be acquired for the understanding of natural things and phenomena.
2. Problem-solving abilities are to be cultivated via the performance of observations, experiments, etc.
3. An attitude is to be fostered that includes emotional aspects such as the love of nature, as well as the 'can-do' attitude needed for solving problems independently.

These three facets correspond to the three items stated above, namely (1) mastery of knowledge and techniques; (2) fostering thinking, decision-making, and self-expression abilities; and (3) competencies regarding students' ability to properly orient themselves towards learning and be emotionally competent (humane, etc.). These are illustrated in Box 8.1. Here, the three pillars of competencies in the course of study for science seem to continue the tradition of the past. That is, the first and foremost priority in the course of study is understanding familiar objects and phenomena, with the objective of acquiring scientific methods and a scientific attitude.

Box 8.1 Objectives of the course of study for science, illustrated through the example of the sixth-grade unit 'Energy and Matter' (MEXT, 2017: 105)

Energy and Matter

1. Students will be able to understand the mechanism of combustion, the properties of aqueous solutions, the regularity of leverage, and the properties and functions of electricity, and will be able to acquire basic skills in observation and experimentation.

   [Corresponds to pillar of competence 1: knowledge and skills]

2. ‘Students will be able to create more reasonable ideas about the mechanisms of combustion, properties of aqueous solution, regularities of leverage, and properties and functions of electricity through their pursuit of them’.

   [Corresponds to pillar of competence 2: competence in thinking, decision-making, and expression]
3. Students will develop an attitude of independent problem-solving through the pursuit of the mechanisms of combustion, the properties of aqueous solutions, the regularity of leverage and the properties and functions of electricity.

   [Corresponds to pillar of competence 3: attitude orientated to learning and humanity]

The key to fostering these competencies is instruction in appropriate scientific perspectives and ways of thinking, which have been defined as follows: ‘In the process of fostering competencies (qualities and abilities), these ways of thinking about and perspectives on things and events, which students can work with and apply’ (MEXT, 2017: 13). Such scientific perspectives and ways of thinking are determined to be incorporated into the *rika* science learning processes in particular. Thus, for *rika* science, a specific framework has been constructed to foster the understanding of natural things and phenomena from a scientific perspective as well as to foster thought processes that contribute to problem-solving.

Firstly, for scientific thought processes, a framework has been set for each school year that includes specific points (facts and events) that are to be given instructional priority. Tasks include making comparisons (3rd grade), thinking about things from multiple diverse perspectives (6th grade); and at junior high school, proposing solutions, analysing, and interpreting results (8th grade), and finally, reflecting on investigative processes (9th grade). By completing each of these tasks, students gain complex metacognitive abilities for reflecting on their own engagements. These can be considered extensions of the items referred to as ‘problem-solving skills’ and ‘scientific inquiry-related skills’ in the former course of study.

From elementary school through high school, scientific perspectives have since 2008 followed fundamental scientific concepts, such as energy, etc. This was part of the reverse course on ‘Pressure-free schooling’ (*yutori kyoiku*) (CCE, 2003), under the rubric of fostering ‘solid academic ability’ (*tashikana gakuryoku*). The establishment of such a conceptual way of looking at things is a further step forward in the policy of a concept-centred curriculum organisation, along the lines advocated by the ASE. Regarding energy-related areas, for example, both relational and quantitative perspectives are used to understand natural things and phenomena.

Table 8.1 summarises scientific perspectives and ways of thinking intended for the content for energy, matter, life, and Earth, respectively, examples of scientific perspectives and ways of thinking, plus specific learning activities, are shown. For energy, the table provides various activities that enable verification via experimentation under controlled conditions. For example, the strength of an electromagnet's magnetic force is made visible by counting the number of paperclips each magnet can pick up and by analysing, from quantitative and relational viewpoints, such things as the strength of the running electric current and the number of coil turns.

These scientific perspectives and ways of thinking provide an 'entranceway' into the observation of facts and phenomena, constituting a means of fostering competencies (qualities and abilities), even though they are different from these end-objective competencies. These are means of proceeding with inquiries in the learning process, and they have been set so that they can be used simultaneously with learned knowledge and techniques. By articulating the perspectives and ways of thinking that have been unconsciously used by those participating in inquiry, it will be possible for all children to participate in inquiry-based activities that are proactive, interactive, and authentic learning. However, if these scientific perspectives and ways of thinking are not positioned as a goal, there is a concern that it will remain unclear where such perspectives and ways of thinking are to be cultivated.

Table 8.1 Scientific perspectives and ways of thinking intended for the fifth-grade unit science 'energy and Matter' (Central Council for Education 2016)

	Energy	Matter	Life	The Earth
Perspective	Quantitative and relational	Qualitative and substantive	Diversity and commonality	Temporal and spatial
Ways of thinking	Students control variables when they predict the factors that they believe influence natural phenomena or events and investigate which factors influence them (control variables)			
Specifically envisioned learning activities (5th grade)	Students investigate conditions that affect the magnetic force of an electromagnet in order to increase the number of clips that attach to the electromagnet	Students will conduct a controlled experiment to determine the regularity of salt dissolving in water. They will also focus on mass to gain a substantive understanding of the fact that matters don't disappear when matters dissolve	Students will investigate the conditions necessary for the germination of green beans. Students will also discover the similarities and diversities amongst organisms by comparing the continuity of life and how it grows with other organisms	Students will examine land formation and changes in land formation from a temporal and spatial perspective. In addition, students will examine the conditions that influence those changes

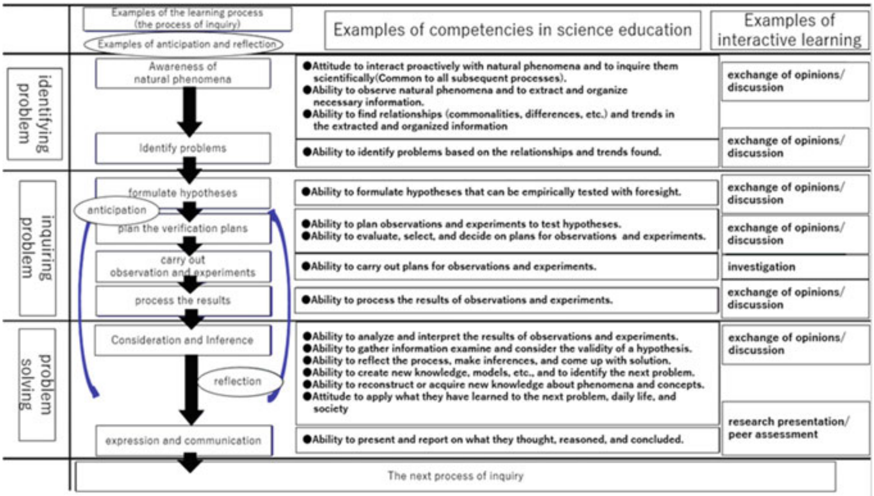

Fig. 8.1 Image of the learning process of science in the course of study (Central Council for Education, 2016: 37)

8.2.3 Learning Processes in Rika *Science that Foster Competencies*

A model of the learning processes in *rika* science that foster competencies is presented in the course of study (Fig. 8.1), intended for all grades. Towards improved *rika* science instruction, the aspects of grasping problem-based tasks, inquiry, and resolution are considered, with the objective of fostering appropriate competencies in this science. To correspond with these, aspects such as the ability to identify problems (3rd grade) and devise solutions (5th grade) are clearly stated in the list of problem-solving abilities that are to be prioritised in each school year (see Fig. 8.1).

Here, we will look at an example for Grade 6 elementary school students concerning the 'mechanisms of combustion'. This case is taken up in example cases created by the National Institute for Educational Policy Research (NIER, Japan) for instruction and assessment in accordance with the course of study. In this unit, the objectives are as follows. First, students identify their questions about the mechanisms of combustion. They then make hypotheses and explore solutions, coming up with ideas that are appropriate for obtaining results. Finally, students express their findings (ability to think, make judgements, and express themselves). Through these activities, students understand that oxygen in the ambient air is used for combustion, resulting in the production of carbon dioxide. They are also taught how to use apparatus and equipment that are appropriate for their target observations and experiment (knowledge and skill). As they pass through these processes, students engage in autonomous (self-driven) learning, fulfilling the objective of fostering attitudes

Fig. 8.2 Children's placement of odour bottles in the experiment

that will enable them to utilise the knowledge they learn in school in their daily lives (attitude of proactive learning) (NIER, 2020).

The unit proceeds according to the learning processes shown in Fig. 8.2. In the first class hour, students observe candles burning within two closed-lid gas collection bottles, one large and one small. Here, students pose the question of how they can get the candles inside each bottle to continue to burn and hypothesise accordingly (this is the setting of problems and hypothesis portion). Students compare the changes that occur in the bottles and share their observations of the events: perhaps they notice that the candle in the smaller bottle is extinguished more quickly or that the flame of the candle in that smaller bottle reduces gradually until it goes out. Their hypotheses may be that the big bottle contains more air, so the candle in that bottle burns longer, or that adding air to the bottles may influence the length of time for which each candle burns, etc.

In the second class hour, based on the students' hypotheses from the first class hour, experiment plans are made, and experiments are then performed. Suppose that some students hypothesised that for a candle to continue to burn inside a bottle, air needs to be introduced. They will first discuss their plan and decide whether it is a good way to test their hypothesis. They will then execute their plan by adding air to the bottle and watching what happens. Here, the students set a lit candle in clay and determine sites at which holes can be made so that air can be introduced. They use the method shown in Fig. 8.2, with a gas collection bottle that has no bottom. To see the flow of air, the students let smoke from a burning incense stick come close to the site where they presume air will enter the bottle.

In the third class hour, students process the experimental results they obtained during the second hour, and then participate in reasoning and inference activities. One student raises the possibility that the candle will continue burning no matter where air enters the bottle. However, by trying different holes in the bottle, the students find that the location of the hole does in fact affect how long the candle burns. As the students consider this gap between their conception and reality, they become aware that not only is additional air needed so that the candle will continue to burn, they also recall that hot air rises, and thus they determine that the hole is best placed at the top of the bottle. The teacher's role is to guide the students as they come up with the correct answer independently.

During this third class hour, it especially emphasised that the students themselves should reflect on their investigation processes in light of a variety of facts. For example, the teacher may ask, 'When the candle is burning and when it goes out, is there any difference in the location of the hole or in the movement of air?' In this way, students are prompted to compare their test results with other groups' results, possibly changing their predictions and/or experimental method, and carrying out another experiment with the knowledge gained from these comparisons. Here, one sees how students reflect on the processes they used in their investigation. In addition, the class collectively considers their thought processes, and students use others' results and considerations to record their thoughts in their notebooks. Through review, reflection, and discussions, students learn procedures they can use to solve problems. They also think of their tasks from a variety of perspectives, fostering ways of thinking that are appropriate for the task at hand. The intention of these strategies is to stimulate ways of thinking about *rika* science in Grade 6 elementary school students.

For each unit, there are also activities intended to help students connect their learning with daily life. For example, students consider how to build a campfire using parallel crosses that allow the passage of air. This idea, that opening paths to accommodate the flow of oxygen will help wood to burn better, comes as the result of having learned the basic principle in class.

In this way, abilities are fostered that enable students to use the knowledge and techniques of *rika* science in their actual daily lives. Especially, to foster academic achievement, learning processes are arranged so that students can actively use their existing knowledge (ex. mechanism of combustion) and skills (ex. designing investigation) according to each context, with the objective of developing the ability to solve problems in daily life and in society in general (ex. building a campfire). These problem-solving processes are described so that they can be undertaken in multiple ways and with various orientations, as in the actual inquiry-like situations students encounter in their daily lives. Forecasted (simulated) solutions and repeated reflection are given special emphasis.

8.3 Significance and Issues Concerning the Science Course for the 2020s

As examined in Sect. 8.1, to achieve both fairness and excellence in science (*rika*) education, the conflict between universality and multicultural diversity of educational content must first be resolved. Towards that end, educational content must be investigated according to the three points summarised at the end of Sect. 8.1—content selected must be clarified in terms of its (1) universality, tempered with (2) multicultural aspects, and there must be (3) a guarantee of fairness.

The course of study points to the fostering of competencies, with abilities rising to a level where they are usable (i.e., applicable in daily life, etc.). To do so, the course of study includes policies that incorporate proactive, interactive, and authentic learning. However, reducing learning to merely ensuring that 'an activity is done' must be avoided. To ensure that activities are geared towards authentic learning, elements of knowledge (but not fragmentary knowledge) must be included, and thus organised and structured by means of general concepts and principles (Ishii, 2015). That entails that students acquire not only knowledge regarding natural phenomena, as was the case in the past, but also that they grasp universal laws and concepts related to that concrete experience.

The Investigative Commission proposed the fostering of scientific perspectives and ways of thinking within courses. This advocates the gaining of an enduring understanding that corresponds to the essential question raised by Wiggins and McTighe (2005) in their theory of 'backward design'. Relying on this essential question, the new course of study implies new possibilities for questioning the structure and system of existing science (*kagaku*), through which there can be qualitative restructuring, and a discarding of outdated knowledge. Through these efforts, students can understand the universal concepts at the core of science (*kagaku*). This path is expected to allow students to gain a uniform grasp of broad-ranging knowledge.

These expectations are betrayed by the following two points. First, the guidelines in the revised course of study consist of qualitative improvements to learning processes, with the objective of instilling a high-quality understanding without reducing the amount of knowledge students must acquire. This suggests that without any cuts to the learning content from the former course of study, changes have only been made in terms of learning methods towards the objective of providing children with higher-quality understanding. However, the educational content in the unit on combustion has been reduced. The facts that combustion is a typical chemical reaction and the three elements necessary for combustion to occur (fuel, heat to the ignition point, and oxygen), which are required for a deeper understanding of combustion, are not taught. In the end, the burden placed on teachers and children becomes heavier, as they are expected to cover a broader range of multifaceted knowledge in addition to the core concepts.

At the time of the Investigative Commission's proposal, it was stated that perspectives and ways of thinking in courses would provide systematic connections between the views on matter, life, and the universe held by contemporary natural science and its core concepts. This approach would converge not only with the mastery of knowledge and techniques (skills), but also be a key to the systematic reconfiguration of educational processes towards fostering an overall viewpoint for conceiving nature (Onuki, 2019). In fact, in the unit on combustion, students learn that one aspect of chemistry is the extraction and analysis of unknown substances through the changes in the properties of substances before and after the chemical reaction of combustion. Nevertheless, the fact is that perspectives and ways of thinking as finally depicted in the course of study for *rika* science reduced these to only one means of studying natural phenomena. There was no connection with the careful selection and systematic education revision proposed by the Investigative Commission, along the lines originally advocated by the ASE.

The result is the risk that rather than learning deeply about axial concepts that are considered universal in *rika* science, there may be excessive coverage of shallower content. This can be understood through the example of learning about combustion, as previously described. The learning here involves only a superficial understanding of combustion gained by persistent work on solving the problem of how oxygen moves and noting its effects. Classes may become stereotypical, with learning stopping after students memorise the names of the gases that comprise ambient air. As ASE member Eizo Ono has indicated, there has been an insufficiently careful selection and arrangement of knowledge and skills. Consequently, classes become insubstantial efforts at problem-solving, which is an approach that sacrifices any maturation of students' knowledge and skills (Ono, 2017).

On the basis of this indication, the classes on combustion described above can be reconceptualised as follows. First, there is the highlighting of core concepts, including the fact that three elements are needed for combustion, and that combustion is a phenomenon (chemical reaction) whereby oxygen and other matter combine to form a different substance. Next, is the careful selection and arrangement of the materials needed for these developments (such as investigation of the structural configuration of the paper hotpot used in the experiment, etc.). Finally, a structural analysis of the elements for combustion is necessary, as well as content on measures that can be adopted to prevent fires at home and learning about the principles of fire extinguishers as well as other aspects of this science, as it is incorporated in the culture and daily life. This would lead to a questioning of knowledge regarding daily life and would serve to mature and ripen knowledge and skills—learning which students can actively use in their daily lives. Here, the application to daily life builds on scientific principles.

What about the multicultural aspects of educational content? For example, in the Next Generation Science Standards (NGSS) for all grades from kindergarten to high school, seven groups are specified as introducing diversity, including disabled students, students whose native language is not English, and female students (NGSS Lead States, 2013). Then, through case studies about teaching to each of the seven groups, evidence-based teaching strategies are proposed for each, such as using the cultural knowledge that students from major racial and ethnic communities develop through belonging to a community. Acts that attach a stigma to these groups risk making the diversity within each group opaque. However, such children have been indicated as a main part of public education (Takahashi, 2020), and one can find conscious engagements related to the issues of intergroup differences and disparities.

In Japan's course of study for *rika* science, students with disabilities are not only mentioned in the General Principles, but responses for disabled children are incorporated into the sections for each science (*kagaku*). In the General Principles, there are also statements regarding responses for children with relatives in foreign countries, as the number of such children in Japan continues to increase. This is one engagement aimed at including all children in course classes, and it can be assessed positively insofar as these are considerations regarding students' diverse backgrounds.

Nevertheless, the course of study does not contain enough direct statements on other pertinent issues. One example is the problem that female students are in a minority position in *rika* science classes, as has been indicated both abroad and in Japan. One factor hindering female students in *rika* science classes is the fact that they are too often given supplementary roles, such as the task of recording data, meaning that they are not fully involved (Yumoto & Nishikawa, 2004). Research has shown that there is a gender bias in teachers' words and actions, and policies have been shown to improve instruction methods (Inada, 2019). In certain foreign countries efforts have been made to promote science learning amongst female students, including improving the selection and arrangement of educational content via systematic revision in consideration of the linkages between science, the human body, nursing science, and other topics. Moreover, efforts are being made to ensure that arrangements and instruction methods accord with female students' experiences and interests (Inada, 2019). There are research findings on the inclusion of people who have been relegated to the periphery in traditional science education. However, the current course of study for *rika* science only reflects a fraction of these findings.

Considered from the point of view of equality in education, the course of study also lacks sufficient policies to support students with disabilities and students with relationship ties to foreign countries. For example, in the course of study for *rika* science, the following is stipulated:

> In regards to students with disabilities, etc., there shall be planned and organised engagements regarding instruction content and instruction methods to ensure that these are appropriate for the difficulties that may occur for these students in the performance of study (learning) activities.

However, these efforts have not been pinpointed to changes in learning content nor have they been applied to the substitution of activities. Instead, teachers have arranged apparatus and equipment so that they are easier to use vis-à-vis each student's specific disabilities, and then these students carry out their experiments, etc., under the teacher's watchful eyes.

The situation is similar for students with foreign relatives. The General Principles of the course of study go only so far as to propose that these students' daily life experiences should be taken into consideration in the classroom, with the encouragement of interactive activities. In the United States, research has suggested rethinking the educational content in terms of 'participation', 'equity', and 'diversity' (Onuki, 2017; Rodriguez, 2015). But in Japan no concrete perspectives are delineated to determine what viewpoints should be incorporated into educational content.

Certainly, the classroom is a key site of cultural transmission. Nevertheless, this is not intended to mean that a singular orientation should be made towards any specific culture. Children are not only the recipients of culture; they are also contributors to their culture (Martin, 2002). Culturally and linguistically diverse (CLD) children, that is, children from different races, social classes, genders, etc., contribute to the mastery of a universality that is tempered with multicultural diversity, as they strive to unravel and cope with the strengths that majority groups have and weaknesses that minority groups have in relation to educational concepts.

The objection can be made with regard to said indications that the course of study is first and foremost a guideline that is edited to present only general educational processes and is not intended to cover and include local knowledge. Moreover, the course of study for *rika* science is meant to emphasise the mastery of tried-and-true methods from the past. It is true that by experiencing the processes shown in Fig. 8.2, students may acquire the ability to make self-inquiries, thus moving towards the mastery of local knowledge. However, the methods proposed in the course of study are, after all, effective methods for acquiring a culture (i.e., educational content) that the mainstream has considered valuable and universal.

To break through the current limitations of the course of study, it has become necessary to propose a diversity of methods. Nevertheless, the fact is that the current 'flat' (uniform for all) inquiry method style makes no organic connections with individual knowledge and abilities nor with specific situations for application. Toshio Umehara (2018) has found that the current course of study offers only one-dimensional methods and has indicated that this point is problematic.

Although in terms of instruction methods, the course of study promotes proactive, interactive, and authentic learning, there is no recognition of the roles played by CLD children, who are subjectively and dynamically involved in the generation of culture in the classroom. In one sense, educational opportunities guaranteed in the name of social fairness have meant nothing more than a regression to the pathway on which there is mastery of the educational content that has been set within the existing school systems under the umbrella of specific values (i.e., assimilation). The path is thereby closed to CLD children's participation in the selection of educational content. There is no guaranteed way for such children to add to arguments regarding educational opportunities and their quality to allow these children to contribute to cultural transformation.

One way to overcome these problems is to rethink knowledge learned in the classroom from multicultural perspectives. For example, it is said that Inuit people have words for 20 different types of snow. This reflects practical aspects and knowledge interests that are encountered in their culture and daily lives. In this way, each student's culture (for example, their conceptions of snow) can be introduced into the classroom via authentic tasks. For cultures considered to be minorities, different types of scientific content and methods are introduced within the classroom setting, enhancing respect for that culture. In this way, students become newly aware of previously unknown scientific content and methods; not only do they learn the characteristics and limitations specifically considered in the classroom, but they also become aware of how this learning can be connected when considering and studying any new phenomenon they encounter. This conjunction with multicultural viewpoints, realised via authentic tasks, helps the students to reconsider their own assumed scientific knowledge and systems. At the same time, it serves to prevent fragmentation of multicultural individuals' and communities' different qualities and characteristics.

Presenting children with the opportunity to learn educational content that reflects multicultural aspects, including indigenous science, does not mean that all children are forced to adopt those viewpoints in their understanding of natural phenomena. Rather, it is no more than providing children with a new 'lens' through which to see the world, and it simply gives the children an opportunity to directly experience that way of seeing things (Ogawa, 1998). Enabling children to discover the existence of a variety of such 'lenses' means that when they come to participate in debates in the public sphere, they will be aware that others have different lenses, and they will understand that within their shared rationality, there are also illogical ways of thinking and acting. All this will contribute to reaching satisfying mutual agreements. The fact that these future sites can be secured here and now within the classroom means that by working together, students will find universal knowledge that contains values they can all share (co-creation).

8.4 Conclusion

In a knowledge-based society, persons must have the ability to deal with existing knowledge, which, compared to the past, has greatly expanded in both quantity and quality. Just as in the past, when Herbert Spencer (1861) asked 'What knowledge is of most worth?', education constantly faces the tasks of refining its selection processes and revising its structural configuration, so that it can deal with—especially today—the enormous expansion of knowledge and its role in social and economic life. In foreign countries, these efforts are made in parallel with the setting of standards, wavering between the desire for universality and the need for multicultural diversity.

In Japan, however, there has not been sufficient investigation into how the course of study system can achieve both universality and diversity in terms of educational content. This is partly because natural science has not been traditionally seen as the primary outcome of *rika* science, and partly because the government has maintained the myth that Japan is a mostly monoethnic and monocultural country. The result is that in the name of science, content that relies on certain majority groups' values are impressed upon students, resulting in the inclusion and exclusion of specific groups. The end result is that both excellence and fairness are sacrificed.

As globalism continues its expansion, there is an ascendent logic that places importance on universal knowledge that is shared across global sites. However, as in the example of primatology research, which has presented the roles of women as making a significant difference, there is an increasing focus on indigenous knowledge, for example, in regional environmental studies. There are also questions regarding the comparative nature of local knowledge and, indeed, with respect to knowledge hitherto considered to be 'universal'.

Moreover, this questioning of universal knowledge can be connected to the guarantee of securing fair and just educational opportunities for children who have been marginalised in learning about science in the past. Nevertheless, despite the inclusion of diverse children within the classroom via the improvement of the education system and instruction methods, and even with the participation of all in proactive, interactive, and authentic learning under the new course of study, little meaning will be derived if teachers are not afforded sufficient chances to consider and debate the political aspects of the educational content incorporated into the course of study. Without such opportunities, children who do not share the knowledge that is considered to be universal will consequently be forced to assimilate into a culture which is not their own. This exclusion puts fairness at risk.

There is a need for such questioning of universalism from multicultural viewpoints, especially as provided by CLD children, for the co-creation of new values. Value creation will in turn promote processes for guaranteeing fairness in knowledge that strives towards excellence. To realise these objectives, efforts need to be made to explore ways of incorporating into the framework of the course of study policies and viewpoints that will enable schools and teachers to also question their past and present educational content. These are the tasks that lie before us.

References

Apple, M. W. (2000). *Official knowledge: Democratic education in a conservative age* (2nd ed.). Routledge.

Apple, M. W., Au, W., & Gandin, L. A. (2009). Mapping critical education. In M. W. Apple, W. Au, & L. A. Gandin, (Eds.), *The Routledge international handbook of critical education* (pp. 3–20). Routledge.

Central Council for Education. (2003). *Immediate measures to enhance and improve curricula and instruction in elementary and secondary education (Report)* [初等中等教育における当面の教育課程及び指導の充実・改善方策について(答申)]. MEXT. https://www.mext.go.jp/b_menu/shingi/chukyo/chukyo0/toushin/f_03100701.htm

Central Council for Education. (2016). *Improvement of the courses of study for kindergartens, elementary schools, junior high schools, high schools, and special needs schools and necessary measures (Report)* [幼稚園,小学校,中学校,高等学校及び特別支援学校の学習指導要領等の改善及び必要な方策等について (答申)]. https://www.mext.go.jp/b_menu/shingi/chukyo/chukyo0/toushin/__icsFiles/afieldfile/2017/01/10/1380902_0.pdf

Inada, Y. (2019). *A study on classroom structure to promote science learning among girls* [女子の理科学習を促進する授業構成に関する研究]. Kazama Shobo.

Ishii, T. (2015). *What academic abilities and learning are needed today?* [今求められる学力と学びとは]. Nihon Hyojun.

Kawagley, A. O. (1998). The indigenous worldview of Yupiaq culture. *Journal of Research in Science Teaching, 35*(2), 33–144.

Kosano, M. (2007). Science [理科]. In S. Yoshimatsu (Ed.), *A guide for curriculum development with children and teachers* [子どもと教師でつくる教育課程試案] (pp. 79–98). Nihon Hyojun.

Kosano, M. (2009). Science [理科]. In S. Yoshimatsu (Ed.), *The nature of subjects and lessons: The history and practice of a civic educational research activity* [教科の本質と授業 民間教育研究運動の歩みと実践 (総論編)] (pp. 100–116). Nihon Hyojun.

Kosano, M. (2018). Where "problem solving" science separated from "content" is headed. *Science Classroom* [理科教室]*, 61*(6), 30–37.

Koyasu, J.(2009). *Introduction to anti-education* (Rev. ed.) [反・教育入門]. Hakutaku.

Mafune, K. (1962). *Theory of science teaching* [理科教授論]. Meiji tosho.

Martin, J. R. (2002). *Cultural miseducation.* Teachers College Press.

Matsuo, T. (2015). *What are 21st century skills?* [21世紀型スキルとは何か]. Akashi Shoten.

MEXT. (2014). *Report of the investigative committee on educational objectives, content, and evaluation based on the competencies to be developed: Summary of issues*. MEXT. https://www.mext.go.jp/component/b_menu/shingi/toushin/__icsFiles/afieldfile/2014/07/22/1346335_02.pdf
MEXT. (2008). *Guidance on the course of study for Elementary School: Science* [小学校学習指導要領解説 (理科編)]. Dainihon Tosho. Toyokan Shuppan.
MEXT. (2017). *Guidance on the course of study for Elementary School: Science*. MEXT.
MOE. (1947). *The course of study for science (Tentative)* [学習指導要領 理科編 (試案)]. Ministry of Education. https://www.nier.go.jp/yoshioka/cofs_new/s22ejn/index.htm
Mori, E. (2017). History of science education: Toward Japanese science education as science education [理科教育の変遷—科学教育としての理科教育へ]. In K. Tanaka (Ed.), *A history of Japanese educational methodology after WWII* (Vol. 2, pp. 81–100). Minerva Shobo.
Morikawa, H. (1969). *Modernisation of science education of secondary school* [中学校理科教育の現代化]. Meiji Tosho.
Nakamura, Y. (1992). *What is clinical epistemology* [臨床の知とは何か]. Iwanami Shoten.
Nakauchi, T. (1988). *First steps in pedagogy* [教育学第一歩]. Iwanami Shoten.
National Institute for Educational Policy Research. (2020). *Reference materials on learning assessment for the "integration of teaching and assessment": Elementary school science* [「指導と評価の一体化」のための学習評価に関する参考資料 小学校 理科]. https://www.nier.go.jp/kaihatsu/pdf/hyouka/r020326_pri_rika.pdf
NGSS Lead States. (2013). *Next generation science standards* (Vol. 2). National Academy Press.
Nishioka, K. (2016). *Curriculum design for subjects and integrated learning* [教科と総合学習のカリキュラム設計]. Tosho bunka.
Nishioka, K. (2017). Historical overview of curriculum organisation. In K. Tanaka, K. Nishioka, & T. Ishii (Eds.), *Curriculum, instruction and assessment in Japan* (pp. 11–27). Routledge.
Ogawa, M. (1998). *Rediscovering science* [「理科」の再発見]. Rural Culture Association.
Ogawa, M. (2006). *At the crossroads of science and education* [科学と教育のはざまで]. Toyokan Shuppan.
Ono, E. (2017). Pillars supporting Science education in the course of study [学習指導要領・理科を支える柱-知識・技能の習得と熟達]. In National Association for the Study of Educational Methods (Ed.), *Educational methodological study on the revision of the course of study* [学習指導要領の改訂に関する教育方法学的検討] (pp. 84–95). Tosho Bunka.
Onuki, M. (2017). Significance and issues of "Next Generation Science Standards" in the United States [米国の『次世代科学教育スタンダード』の意義と課題-『卓越性と公正性』の側面に着目して-]. *Bulletin of the Association of Educational Objectives and Evaluation, 27*, 59–68.
Onuki, M. (2019). Science [理科]. In K. Nishioka & T. Ishii (Eds.), *Performance assessment to realize 'deep learning' in subjects* [教科の「深い学び」を実現するパフォーマンス評価] (pp. 64–77). Nihon Hyojun.
Okada, A. (2013). *Equality of educational opportunity* [教育の機会均等]. Gakubunsha.
Rodriguez, A. J. (2015). What about a dimension of engagement, equity, and diversity practices? *Journal of Research in Science Teaching, 52*(7), 1031–1051.
Schiebinger, L. (1999). *Has feminism changed science?* Harvard University Press.
Science Council of Japan. (2010). *Prospects for the field of pedagogy* [教育学分野の展望—「質」と「平等」を保障する教育の総合的研究—]. http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-21-h-1-4.pdf
Spencer, H. (1861/1911). What knowledge is of most worth. In *Essays on education and kindred subjects* (pp. 1–44). Everyman's library [originally published by Williams and Norgate, London]. https://oll.libertyfund.org/title/eliot-essays-on-education-and-kindred-subjects-1861-1911
Takahashi, K., & Hosoya, J. (1974). *An introduction to the polar method* [極地方式入門]. Kokudosha.
Takahashi, T. (2020). "Vacillating" of Japanese Style Public Education due to "inner globalization" [『内なるグローバル化』による日本型公教育の『揺らぎ』]. In T. Omomo & H. Seto

(Eds.), *Reconsidering Japanese-style Public Education* [日本型公教育の再検討] (pp. 63–88). Iwanami Shoten.

Tanaka, K. (1994). Educational content and methodology [教育の内容と方法]. In Y. Sugiura (Ed.), *Pedagogy* [教育学] (pp. 79–123). Yachiyo Shuppan.

Umehara, T. (2018). "Scientific Inquiry" comes to the fore [『科学的探究』の前面への出現]. *Science Classroom* [理科教室]*, 61*(12), 35–41.

Wiggins, G. P., & McTighe, J. (2005). *Understanding by design* (2nd ed.). Association for Supervision and Curriculum Development.

Yumoto, H., & Nishikawa, J. (2004). Interaction among students during science experiments [理科実験における学習者の相互作用の実態と変容に関する研究]. *Journal of Research in Science Education, 44*(2), 83–94.