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Meeting the Needs of Twice-Exceptional Children in the Science Classroom

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1. Introduction

Since 2007, special needs education in Japan, in addition to the disabilities targeted in special education in the past - such as visual disorders, hearing disorders, intellectual disabilities, physical handicaps, health impairments, speech disorders, and emotional disturbances – also encompasses Learning Disabilities (LD), Attention Deficit/Hyperactivity Disorder (ADHD), and High-functioning Autism (HA) and Asperger's syndrome. These are considered to be mild developmental disorders in Japan. In the survey results of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2002, teaching staff noted pronounced difficulties in learning and/or behavioural problems in 6.3% of students in public primary schools (MEXT, 2003). Based on responses to each item in the survey, it is estimated that 4.5% of these students may have LD, 2.5% may have ADHD, and 0.8% may have HA (Japan Association of the Special Educational Needs Specialist, 2007).

Children screened for disorders are sometimes identified as having gifted characteristics. Children screened for their giftedness are sometimes identified as having academic or behavioural disorders. Regardless of the order in which they are screened, identified children can have the combined characteristic of both giftedness and developmental disorders (e.g. Baum, 2004; Cooper et al., 2005; Weinfeld, Barnes-Robinson, Jeweler, & Shevitz, 2006). "Twice-exceptionality" (heretofore referred to as 2E) is the term used for someone who is gifted or talented and at the same time has one or more learning difficulties or disabilities (Buttriss & Callander, 2005). It is evident in the extant literature that few conceptual or practical studies, which focus on the gifted traits that the majority of these children possess, have been conducted in a specific subject area in detail.

The criteria for gifted identification are usually domain-independent, such as IQ, creativity, and leadership. However there are many good science programmes for the gifted. Sumida (2010) noticed four reasons why 2E children are adept at learning science. These are (1) the domain-specific, dynamic nature of science, which encompasses a wealth of different fields of study, can accommodate children's varied areas of interest; (2) hands-on activities in science learning can promote creative ideas and lead to a persistence in children that often surpasses their teachers' expectations; (3) an integrated scientific approach will be beneficial in that the children's dominant strengths can be reinforced and developed in a broader context; and (4) science encompasses collaborative learning activities in the laboratory and in the field within self-established norms and the sharing of basic attitudes and ways of thinking. Karns, Shaunessy, & Bisland (2004) suggested that developing 2E students use interest and learning style inventories to become familiar with the strengths of their own strengths.

The purposes of this research are as follows: (1) to design and implement a primary science lesson to meet the needs of a 2E child and (2) to analyse a 2E child's writings on worksheets and laboratory notes, and compare these with those of regular children.

2. Methodology

2.1 Identifying twice-exceptional children in science

In this study, 2E children in science were found in an urban city in Japan. The city board of education has a three-stage systematised framework for profiling children with mild developmental disorders. In the first screening, all children in the city are observed using a general checklist to identify characteristics of children with developmental disorders. The second screening is conducted using a checklist designed to specifically identify the type of developmental disorder. The third screening includes the Wechsler Intelligence Scale for Children-Third Edition-(WISC-III), the Japanese Kaufman Assessment Battery for Children (K=ABC), the Illinois Test of Psycholinguistic Abilities (ITPA), and other similar developmental surveys; scholastic records; and information about home environments and early developmental history.

In the screening for giftedness in science, Sumida's Gifted Behaviour Checklist in Science for Primary Children (Sumida, 2010) was used for primary children at eight schools randomly chosen from 62 primary schools in the city. The checklist consists of 60 items, is focused on: Attitudes, Thinking, Skills, and Knowledge/Understanding in science. Using factor analysis, three factors were proposed as "General Competence in Science," "Competence in Science regarding Natural Thing," and "Creative Competence in Science," and a cluster analysis with subscale points for each factor identified three "gifted styles" in science. These were: (1) Spontaneous Style, (2) Expert Style, and (3) Solid Style. Sumida (2010) found that LD/ADHD/HA children displayed the Spontaneous Style, while non-LD/ADHD/HA children were characterized under the Solid Style. The number of children exhibiting the Expert Style was the lowest, with no significant difference between the two groups.

In Sumida's study (2010), 13 out of 86 children were in the Expert Style Group; five of these children had LD/ADHD/HA. The subject of this study was one of the LD/ADHD/HA primary children in the Expert Style Group.

2.2 Profile of the twice-exceptional child in this study

The twice-exceptional child targeted in this study was a 4th grader at a public primary school in an urban area in Japan. Sumida (2010) classified him as an "Expert Gifted Style" child with LD/ADHD/HA. His scores for "General Competence in Science," "Competence in Science regarding Natural Things," and "Creative Competence in Science" were high, at 2.95, 3.00, and 2.88, respectively.

In this study, before the science lessons were designed, the teacher of the student's class and the science teacher were interviewed about his school life. Both teachers remarked that his difficulties involve unnecessary movement of extremities unless he takes medication. Further, he speaks too loudly, unbefitting the circumstances. Since 4th grade, the child has been prescribed medication but individuals around him claim that there seems to be no notable difference in behaviour when the child takes medication.

The child is well built. He belongs to a softball team and participates enthusiastically, due to the influence of his parents. He exhibits average performance in music, art, and physical education. Generally, he reads many books and has a wealth of knowledge acquired through day-to-day activities. He is well versed in Kanji (Chinese characters) and can sometimes read characters that have not yet been taught in school. He belongs to the *shuji* (calligraphy) club. He has a broad vocabulary and sometimes uses phrases uncommon to 4th graders.

On the other hand, he finds it somewhat difficult to use his imagination and to draw mental pictures. He cannot respond spontaneously and dawdles from time to time. He is not very dexterous with his hands. His sketches and use of colours during art lessons are below average for a 4th grader. He also experiences extreme emotions; there are times when he appears satisfied with the results of his crafts and there are times when he seems very frustrated. He refuses to stop promptly halfway through an activity and has his own mind-set concerning the finishing of an activity. Problems often occur not only during lessons but during break times as well. The child seems somewhat inflexible in his relations with his peers. He may say something unwarranted during break times and set off arguments. Sometimes the child finds it difficult to ignore a friend's comment. Remarkably, troubles have diminished in the period from the first to the second school term.

Prior to these changes in his social behaviour, the child was easily distracted. Presently, he corroborates well with his fellow group members when carrying out experiments and he does not speak as loudly as before. At the same time, his science teacher noted that the child's interest and desire to learn and solve problems became remarkably strong. During science classes, the child responds well to questions raised by the teacher. He can express his own ideas with a wealth of knowledge. When predicting results, he can now thoroughly contemplate the topic and express his thoughts. The child speaks clearly and confidently when commenting. For example, he mainly operates the stand and alcohol lamp properly in the group during an experiment on the three states of water. He takes the initiative and works hard. He does well in tests and seems to show good understanding of the topics that have been studied. Specimens of plant collections submitted for his project over the summer holiday were great. The stems were cut, opened, and taped for display as if a professional in plant collecting had taught the child. However, he seems to show no particular interest in insects.

2.3 Designing science lessons for the twice-exceptional child in a regular classroom

Jewer et al. (2008) proposed a framework and graphic organizational planning tool designed for teachers to use with any instructional materials for 2E students. However, research on the practice and its effects on 2E students are very limited in science. In this study, a science lesson about "How Things Heat Up" was designed for the 4th grade and implemented in a public primary school. This unit includes activities such as investigating the way three materials (metal, water, and air) heat up, and tapping experiences at home and at school. The important goal of the unit is to inspire interest and curiosity regarding the questions that arise from this investigation and to cultivate scientific ways of thinking about the basic properties of materials by having children pursue these questions further while using these activities as a means to consider how heat is conducted through metal, water, and air. Dole (2000) notes that gifted students with learning disabilities require a problem-based curriculum with hands-on experiences. Characteristics of heating include the way metal quickly conducts heat, whereas water and air can only convey heat through convection, which takes a longer amount of time. The contents of this unit were broadly divided into five parts as shown in Figure 1 (one through five). The unit takes a total of 11 hours.

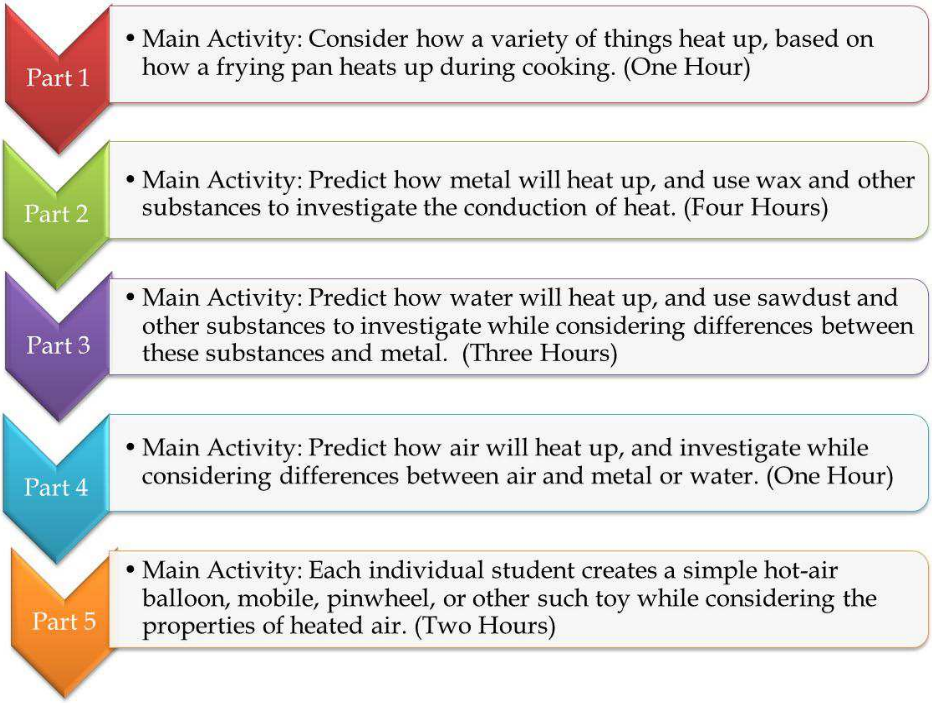


Fig. 1. Unit flow and composition of main activities of the lesson (11 hours)

2.3.1 The first part of the lesson (One hour)

The goal of the first part of the lesson was to "have children predict how a horizontal metal rod will heat up and make them interested in and curious about how a variety of different substances heat up." The students were shown a frying pan and electric stove being used for heating, and were made to consider how heat is conducted, as well as how temperature changes. In order to measure the change in temperature, a radiation thermometer was used to measure the centre and periphery of the frying pan, and by both predicting and experiencing the changing temperature for themselves, students were inspired to be more interested in and curious about heating.

In this part, the use of a radiation thermometer, which is an advanced measurement instrument that one does not often see, helped the students experience for themselves how the temperature heated up beyond 100° C, especially in the case of metal, which became extremely hot. The experiments not only made it possible for the students to predict that the substance would grow extremely hot, but also taught them how to handle equipment during an experiment, how to clean up after an experiment, and so on, while enabling them to participate in activities designed with safety in mind.

2.3.2 The second part of the lesson (Four hours)

During the first class teaching of the second part of the lesson, the students conducted experiments by watching the melting of wax, to see how a metal rod would heat up and understand the order of heating from area to area. During the second lesson of the second part, the students conducted additional observational experiments using wax with a diagonally oriented metal rod, to understand the order of heating and how it is affected by the new angle. Next, during the third lesson, the students predicted how a plate-shaped piece of metal would heat up while discussing methods of determining how it is heating up and considering for themselves experimental methods and how to make preparations. Finally, during the fourth lesson in this part, the students used the method and materials they came up with during the previous class in their own group, conducted experiments regarding how a metal plate heats up, and summarized their findings.

Specifically, during the first class, the students made predictions about experiments in which they would heat metal rods of approximately 30 cm in length from the centre with alcohol lamps. The students used wax as part of the experiment, in order to verify how the heat was conducted by watching the wax melt. Next, during the second lesson, the students predicted how the rod would heat up with the rod slanted at an angle. During the third and fourth lesson of this part, a 30 cm by 40 cm metal plate was used to investigate the heating of the surface of a flat piece of metal. During these experiments, the children were made to consider methods for telling how the object was heating up, such as whether to use substances that melt or harden when heated. As the lesson proceeded, groups of children were made to discuss what materials and methods to use for the experiment.

The worksheets for predicting how heating would occur were of a format that allowed for filling in elapsed times, with items such as "Beginning," "After _ Minutes," another "After _ Minutes," and so on. The children were made to fill in the times they decided upon in "After _ Minutes" time settings, thereby enabling them to make predictions while being conscious of the time it takes for an object to heat up. In addition, the innovation whereby children are made to record their observations about heating using colours, arrows, lines, and other such methods of classification elicits more concrete and complicated ideas. For the colours, low-temperature parts were coloured in using blue, and high-temperature parts were coloured in using red, making it possible for the children to express their ideas regarding heating both visually and continuously. Children were also made to classify changes in temperature and the conduction of heat with arrows and lines, to fill in predicted temperature values using numerical values, and so on, and this helped the children to refine their predictions and gain the ability to express predictions numerically.

2.3.3 The third part of the lesson (Three hours)

The third lesson involved investigating how water heats up. During the first class's experiment, a test tube filled with water was tilted and heated from the middle using an alcohol lamp. Thermal tape that would change colour when heated to 40° C or above was placed on a glass rod, and this was used to investigate how the tube heated up. Next, in order to even more closely investigate how water heats up from the top, during the second and third classes, a 300 cm^3 beaker was used in additional water heating experiments. While conducting their own experiments to investigate the convective flow of water, the students also used thermal tape to investigate the changing temperature at several locations inside the beaker, and summarized what they learned.

To investigate convection and heating in the water, the students discussed within their groups how to place items in water, as well as thermal tape affixation methods. To view the water's convection, the students selected substances such as sawdust and tea leaves, while also discussing where to place the substances and how much to use. In addition, four or five glass rods with thermal tape applied were distributed to each group, and the students were asked to think of ways to investigate how the overall temperature would change. Furthermore, as part of a demonstration experiment, a large 3,000 cm^3 beaker, sawdust, thermal tape, and a thermometer were used to observe the water's convection and changing temperatures.

2.3.4 The fourth part of the lesson (One hour)

The experiment in the fourth part of the lesson involved measuring changes in air temperature as a space thermostat heated up the science room. Inside the science room, desks were arranged so that seven groups of four children each could sit, and three locations were decided for measurement at each group, with rod thermometers used to measure temperature twice—before the space heater was turned on and ten minutes after it began heating the room. The three measurement locations were (a) at the height of a standing student's eyes (approximately 1.2 m from the floor), (b) near the floor of the science room (several centimetres off the floor), and (c) as high as a student standing on the desk could reach (near the ceiling). Each group used three thermometers and shared responsibilities for various tasks in the experiment.

An activity that makes use of an everyday situation, where individual students can independently measure temperatures in order to investigate and learn about how air heats up, is not only a better way to increase interest and curiosity on the part of each student than using textbooks and guidebooks but also leads to an understanding that comes from actually experiencing the phenomenon for oneself. Also, to prevent the students from moving around the classroom and disturbing the convection of the air for the ten minutes during which the space heater was heating the room, they were constantly reminded to remain seated and watch audio visual teaching materials about the heating of metal and water. These materials gave the students the opportunity to consider the floating of a hot-air balloon (the subject of the fifth part) and the characteristics of heated air and to review the concepts they had learned.

2.3.5 The fifth part of the lesson (Two hours)

During the fifth part of the lesson, students verified what they learned about how air heats up, and constructed objects as part of an activity to utilize the property of air whereby it rises when heated. Each child selected a certain item to create from among three options (a hot-air balloon, a mobile, or a pinwheel), and was allowed to use their own creativity and strategies to determine aspects such as the size, shape, and decorations of the item. After a simple explanation of materials and methods of construction, the class was split up into groups of student making the same objects. Furthermore, since this activity involved the use of hair dryers and gas stoves, the children were also given safety instructions and instructions about handling equipment and avoiding accidents.

During the construction activity, each student was provided with materials and methods so that the students could come up with their own way of making their objects. For the hot-air balloons, plastic was provided with a thickness of approximately 0.01 mm and a size of around 90 cm by 90 cm, so that hot air from a hair dryer would heat it up and cause it to float as part of a large and light-weight hot-air balloon created by the children. Also, tools were utilized that made it possible to cause plastic to stick to objects after being heated by a heating wire. This enabled quick and easy construction. For mobiles and pinwheels, a small gas stove was provided, and the students performed the experiment while paying attention to safety issues. Three types of teaching materials were prepared, and students were placed into learning groups according to the options.

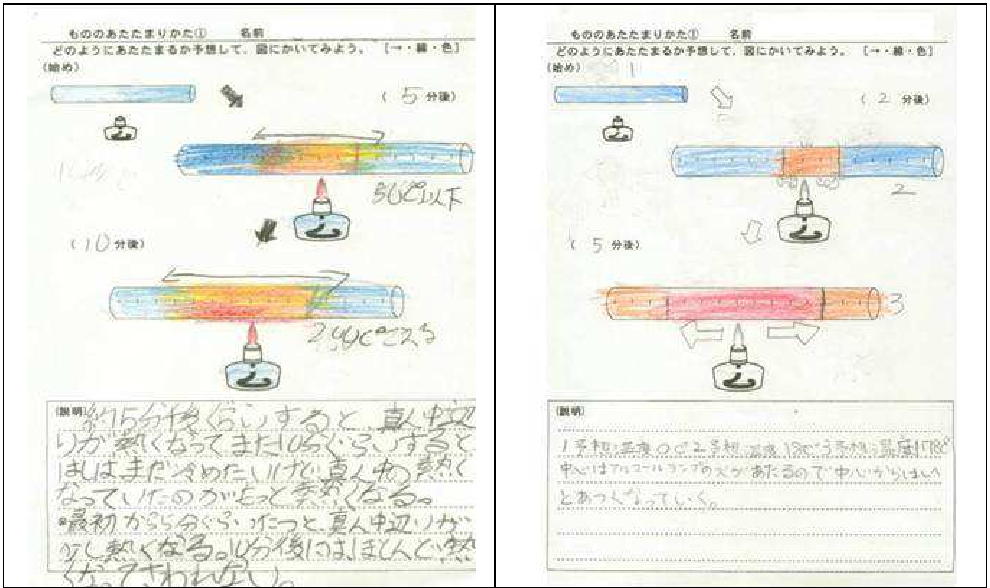
3. Results

3.1 The first part of the lesson (One hour)

By showing the frying pan one uses to cook, the science teacher raised the children's level of interest and curiosity. He listened to the opinions of the children regarding predictions of the frying pan's surface temperature, and got the impression that children usually do not have a sense of what temperatures in excess of 100° C are like. It seemed that their most familiar experience with temperature was the use of an alcohol thermometer during a science lesson about boiling water. Worksheets used by Student A and Student B are shown in Figure 2. Student B is the student of the same gender as Student A, with the closest birthday in the class.

Student A was able to predict the way the metal rod would heat up while considering time and temperature. He represented the differences in temperature by using lines as scale marks, with colours showing the differences in temperature. Student B was able to make the same representation in the worksheet.

In the class, Student A predicted that the temperature would reach "around 200° C," giving the impression that this student is well-versed in scientific knowledge, through information attained from television and other media, or from books and other types of reference documents. When the science teacher introduced thermal tape, Student A even mentioned "thermography." The student seemed to have a rich array of experiences from everyday life and to possess a powerful interest and curiosity regarding scientific phenomena. This student also used colours to indicate temperatures after the metal rod was heated for five or ten minutes, using arrows while making predictions not only envisioning the differences between the centre and rends but also envisioning specific temperatures that would differ at different levels of heating depending on the location on the metal rod, such as the top and bottom of the central part of the rod where it came into contact with the flames of the alcohol lamp.



Student A	Student B

Fig. 2. Worksheets (for prediction) during this part of the lesson by Student A and Student B (Student B is the student of the same gender as Student A with the closest birthday in the class)

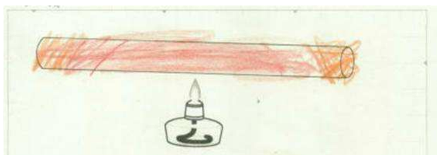
3.2 The second part of the lesson (Four hours)

The goal of the first hour of the second part of the lesson was to use wax to observe how metal heats up and understand the process of heat gradually spreading from the heated part. This activity was performed with the children split into groups, cooperating while carrying out the experiments, sharing responsibilities, and helping each other. Many of the children carefully observed how the wax melted, how the temperature changed, and the amount of time it took until the metal heated up, while using colour classification, arrows, and other methods to summarize experimental results and what they learned in their notes, which they then presented while verifying the opinions of their friends. Figure 3 shows worksheets in this lesson by Student A and Student B.

As shown in Figure 3, Student A used a stopwatch to measure the elapsed time and record the experimental results, classifying temperatures using colours while representing heating using arrows. He realized that the temperatures were different at the left and right ends. Also, he observed how the metal rod cooled after the alcohol lamp was extinguished. Student B recorded the experimental results by representing heating through the use of colour classification. However, he did not record concrete results in detail, and did not sufficiently represent heating.

During the experiment preparation stage, all of the children gathered around the experiment desk, thinking about experimental methods, verifying procedures, and then proceeding with the lesson. Among the children, Student A always stood close by the teacher's side, mumbling ideas and thoughts while earnestly working on the lesson. The experiment of spreading wax on a metal rod and heating it with an alcohol lamp was conducted by groups of children who shared and swapped responsibilities throughout the experiment. Student A's group was the first one in the class to start working on the experiment. In addition, while verifying operations and measurement results, the group considered places where things were not going well, asking the teacher to take measurements with the radiation thermometer and otherwise proactively participating in the experiment and observations. Student A not only observed how the metal rod heated up, he also continuously observed how the rod cooled off. He was confident in his experimental findings that the metal rod heated up differently on the left and right sides, and in his notes, he meticulously summarized the results using colour classifications, arrows, and numerical values.

Student A

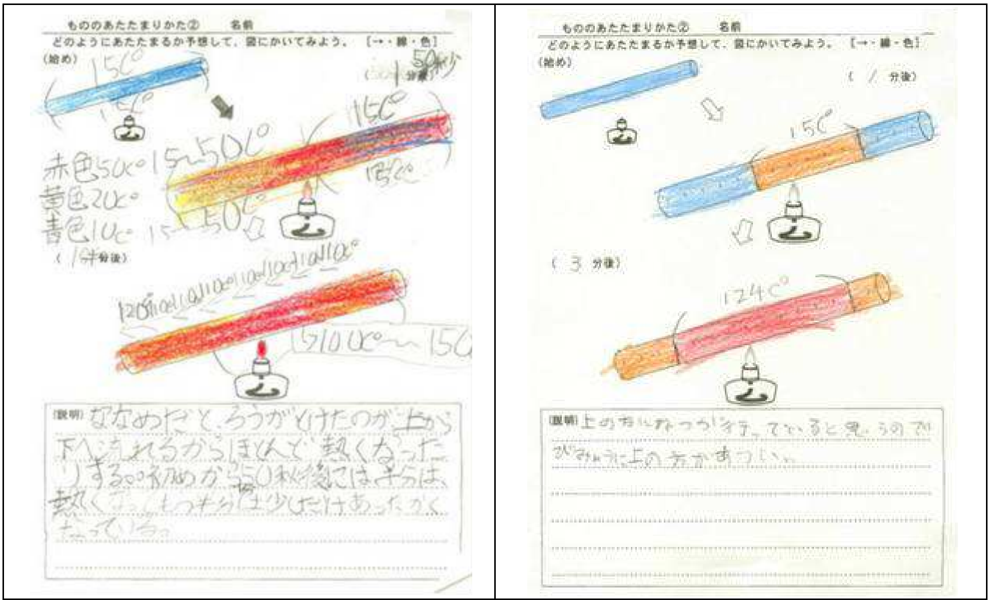


Student B

Fig. 3. Worksheets (for results) by Student A and Student B

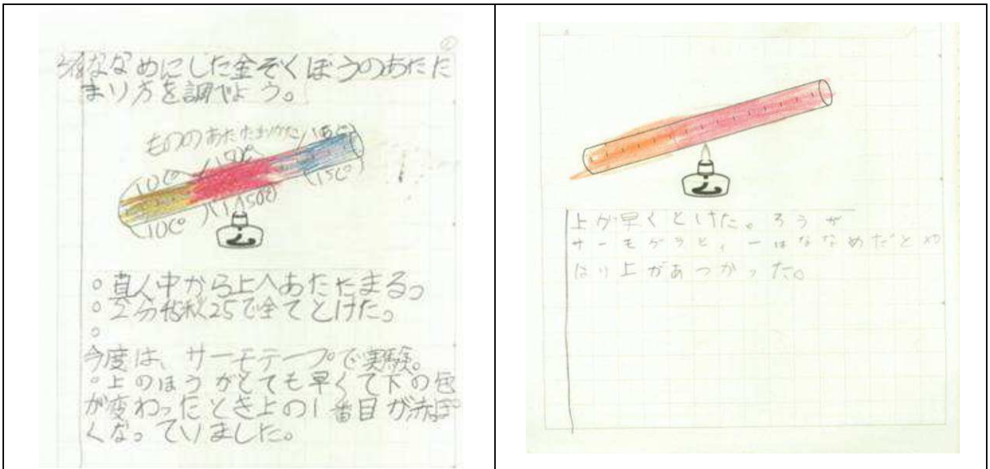
The goal of the second hour of the second part was to make students understand that even when the rod is at an angle, it will heat up gradually from the place where heat is applied. Many students predicted that as the slanted metal rod is heated, the flames will burn upward, so therefore heat will conduct more readily upward. The worksheets of Student A and Student B are shown in Figure 4 and Figure 5.

In the prediction, Student A took advantage of the results from the experiment during the previous class (1 minute and 50 seconds for full melting) in order to precisely determine the time it would take for the slanted metal rod to heat up, while using colour classification and arrows to represent predictions in detail. Student B made similar considerations as well.



Student A	Student B

Fig. 4. Worksheets (for prediction) by Student A and Student B



Student A	Student B

Fig. 5. Worksheets (for results) by Student A and Student B

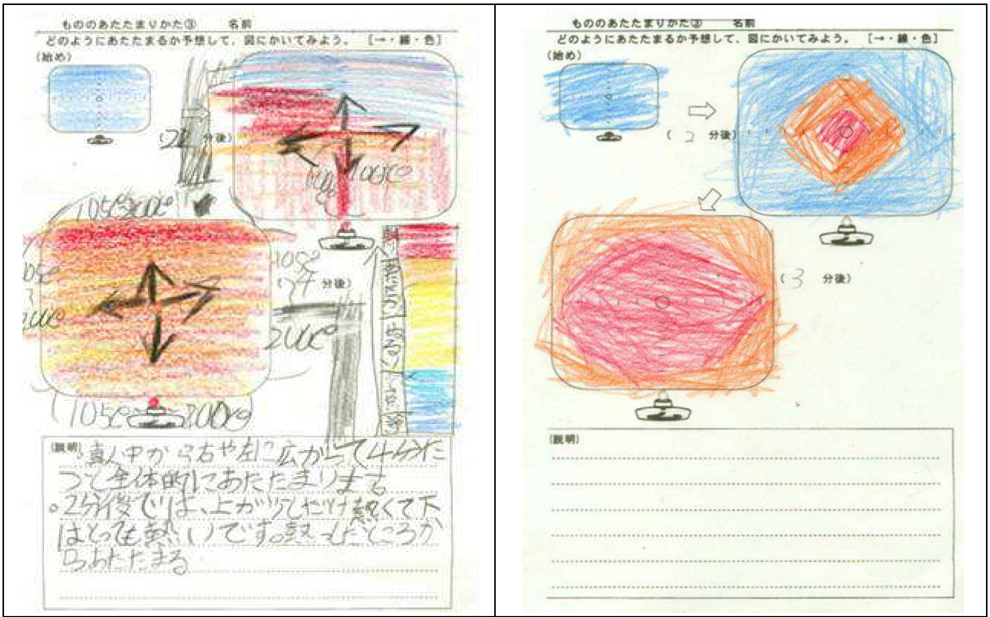
As in Figure 5, Student A used a stopwatch to measure the elapsed time during the experiment and represented the results by using colour classification. He asked the teacher to measure the metal rod's surface temperature and recorded the findings. He also realized that the temperature differed slightly between the top and bottom of the metal rod. Student B however only wrote that the wax melted on the top part of the metal rod and did not sufficiently represent how heating occurred by indicating information such as the order in which the wax melted and the time that it took to melt.

During the experiment's prediction stage, Student A predicted that the earlier temperature of 15° C for the entire metal rod would increase to around 50° C after 50 seconds, and then reach 150° C after 1 minute 30 seconds. Student A expressed these predictions with concrete, numerical values, while meticulously using arrows and colour classifications. During the experiment, Student A took turns applying wax with another student in the same group. Student A also actively participated in the experiment, affixing the metal rod to the stand while verifying the height of the alcohol lamp, positioning the alcohol lamp while verifying the position of the groove on the metal rod, and otherwise thinking carefully while performing the various procedures. Student A was able to use a stopwatch and radiation thermometer to observe how the metal rod heated from a variety of different positions and recorded these findings. During the presentations, Student A carefully listened to the other students' presentations, and presented the different experimental results of his own group. Student A always made an effort to reason independently while learning.

The goal of the third hour of the second part was to have students predict how a metal plate will heat up, discuss among themselves what methods and materials to use to investigate the heating, and consider experimental methods and what must be prepared. Figure 6 shows worksheets in this lesson by Student A and Student B.

Student A used complicated colour classifications and arrows to represent in detail how the metal plate would heat up, taking time and temperature into consideration. Student B was able to predict how the metal plate would heat up and took time into consideration. Although Student B seemed to represent temperature differences using colour classification, since there was no explanation, he did not sufficiently represent his prediction regarding the heating of the metal plate.

Student A was enthusiastic about this lesson's prediction activity, concentrating for a long time and summarizing predictions with a great level of detail. With respect to the heating of the metal plate, Student A was able to use detailed colour classifications, representing differences in the heating state by referring to temperatures with the following five levels: "hot," "warm," "lukewarm," "slightly cool," and "cool." In addition, Student A predicted that the temperature would be between 100 and 200° C. Regarding the time required for the heating as well, Student A came up with the predictions "after 2 minutes" and "after 4 minutes," recalling the previous metal rod experiments and how long it took the ends of the rod to heat up before. Student A consistently incorporated a variety of previously learned information. While the students were considering their own experimental methods and materials, Student A was also able to make proposals based on foresight regarding what will happen, such as "since it will heat up from the middle, we can place ice in the middle."



Student A	Student B

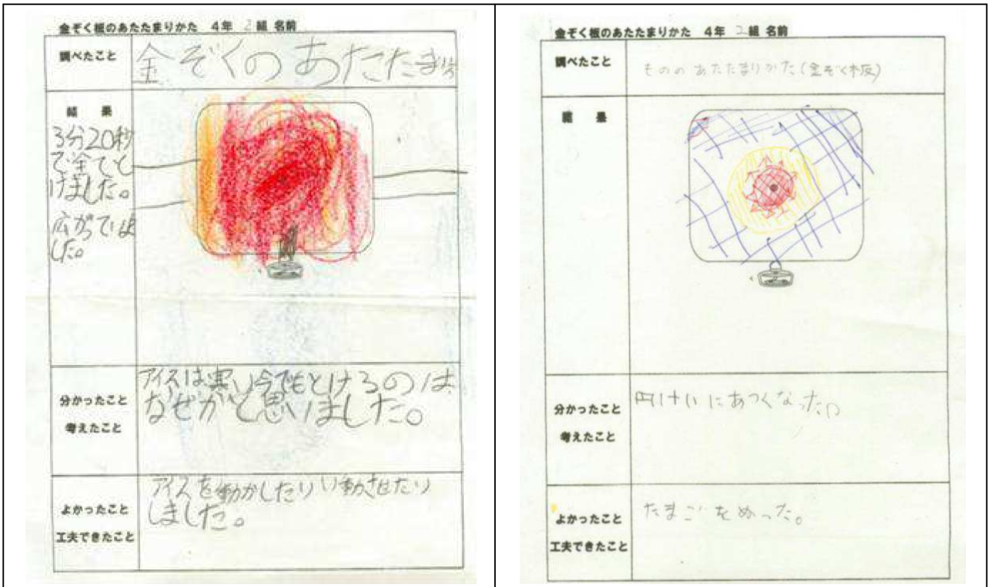
Fig. 6. Worksheets (for prediction) by Student A and Student B

Furthermore, while listening to and considering the predictions of other students, Student A indicated the difference between the predictions of other students that the metal would heat up in a round pattern from the middle, and the predictions of students that it would heat up in a square pattern. Student A carefully listened to the opinions of other students, and while focusing on differences, enthusiastically described these differences. Student A's behaviour is evidence of a proactive attitude towards learning about science.

The goal of the fourth hour of the second part was to have groups of students consider methods and perform experiments regarding how a metal plate heats up and summarize what they discovered. Worksheets in this lesson by Student A and Student B are shown in Figure 7.

Student A used a stopwatch to measure elapsed time, representing this along with the results of the experiment, but did not sufficiently represent how the metal heated up. It is evident that this student came up with a strategy of moving objects to melt during the experiment. Student B represented experimental results with colour classifications and arrows, but did not sufficiently represent the passage of time or changes in the substance that melted.

Moreover, Student A understood the objectives of the experiment and thought with foresight regarding the properties of the materials to use in the experiment, experimental methods, and so on. Student A affixed the metal plate to a stand, and placed the alcohol lamp directly underneath the metal plate through a process of trial and error. Student A's group conducted its experiment using ice. Since the ice was brought by another student in the same group, Student A just watched the other student decide where to place the ice and actually line up the ice. In spite of this, Student A helped by changing the positions of the pieces of ice while thinking of various different ideas for where to place them, while properly summarizing the results, such as how the place where the flames hit the metal is where the heating starts and how the heating spreads to the surrounding areas.



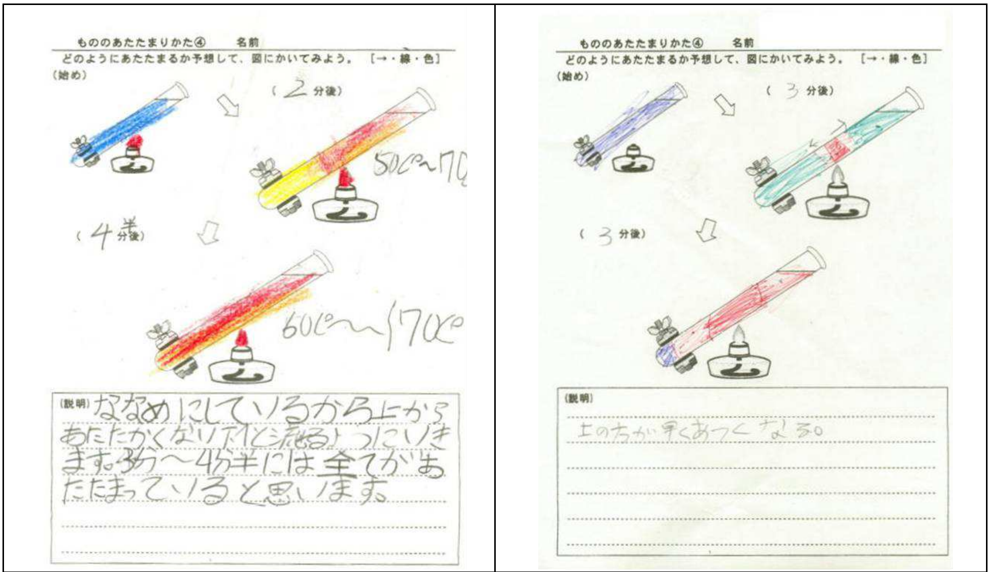
Student A	Student B

Fig. 7. Worksheets (for results) by Student A and Student B

3.3 The third part of the lesson (Three hours)

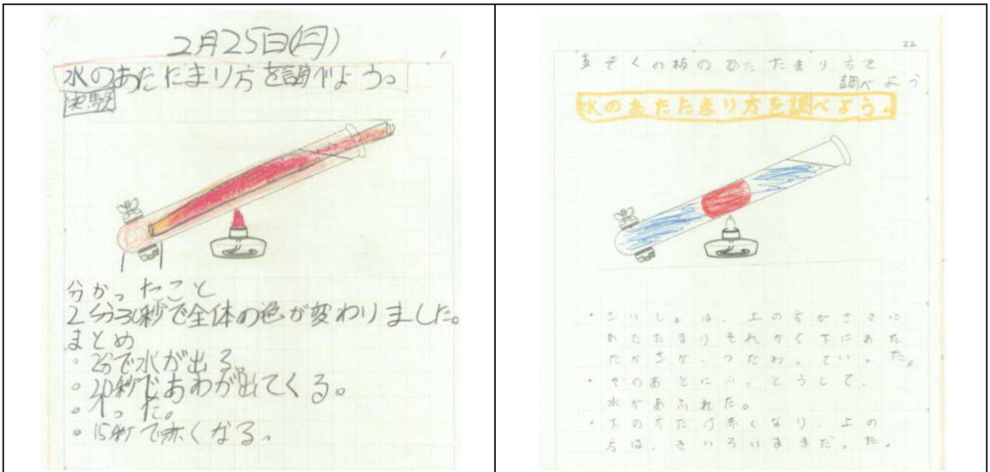
The goal of the first hour of this third part of the lesson was to have the students not only predict how the water in the test tube would heat up, but to also understand that the water gradually heats up starting at a location above where the heat is applied. Figure 8 and Figure 9 show worksheets in this lesson by Student A and Student B.

While considering the concrete times and temperatures involved in the heating of the test tube's water, Student A was able to represent predictions using easy-to-understand diagrams and sentences. He thought that the water would heat up more slowly than metal. Student B seemed to represent temperature differences using colour classification, but since there was no explanation, he did not sufficiently represent his prediction of how heating would occur. Figure 9 shows that Student A used a stopwatch to measure the time elapsed during the heating of the water in the test tube and represented the changing colour of the thermal tape in a concrete fashion. He also observed and recorded in detail how the water changed in the test tube. Student B used descriptions of changes in temperature that did not match descriptions of changes in the thermal tape's colour, and he did not sufficiently represent experimental results.



Student A	Student B

Fig. 8. Worksheets (for prediction) by Student A and Student B

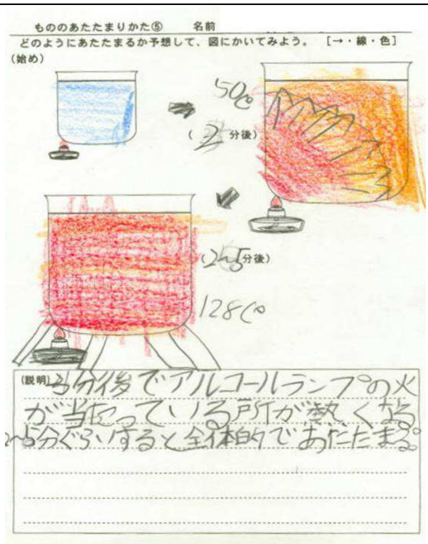


Student A	Student B

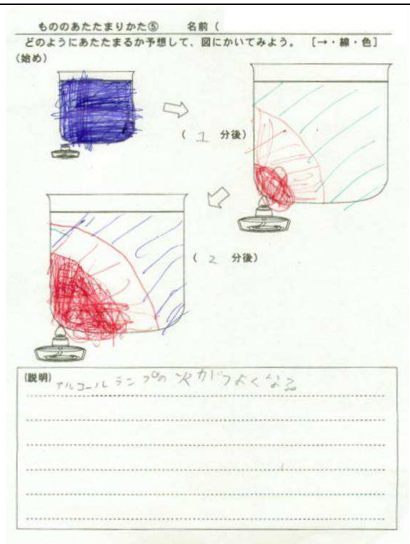
Fig. 9. Worksheets (for results) by Student A and Student B

When the students gathered around the experiment desk to verify the experimental methods during this lesson, Student A once again stood right next to the teacher and presented a variety of impressions and thoughts, evidence of a high level of motivation. After this, Student A voiced concerns about the test tube breaking, clarifications were made regarding the resistance of glass to heat, and the students were told that the test tubes would not break. When predicting how the water in the test tube would heat up, Student A took advantage of his experiences learning about how metal heated up to concretely predict how long it would take for the water to heat up, and he also predicted the temperatures that would be reached. During the experiment, when the water overflowed out of the test tube, Student A quickly obtained a rag and continued observations. During observation, in addition to recording thermal tape temperature changes along with the elapsed time, Student A also carefully observed and recorded the boiling state of the water inside the test tube. Since Student A was able to closely observe changes during the experiment, he was able to successfully present his acquired knowledge and skill.

The goal of the second hour of this part was to have students predict how water in a beaker will heat up and consider and discuss methods for effectively investigating convection and heating in the water. In the predictions using a beaker to investigate how water heats up, when the flames of an alcohol lamp were applied to one side, many of the children predicted that the heating would spread in a round pattern, as with the metal plates. Worksheets of Student A and Student B are shown in Figure 10.



Student A



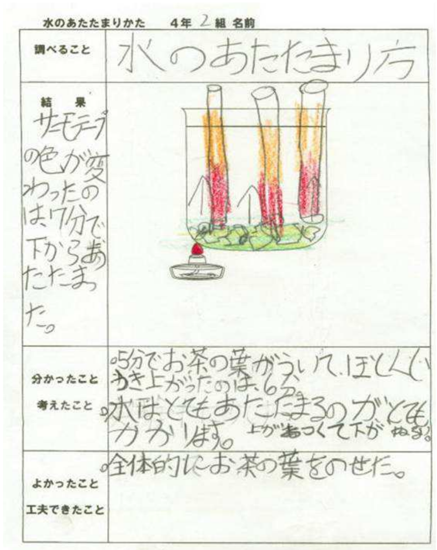
Student B

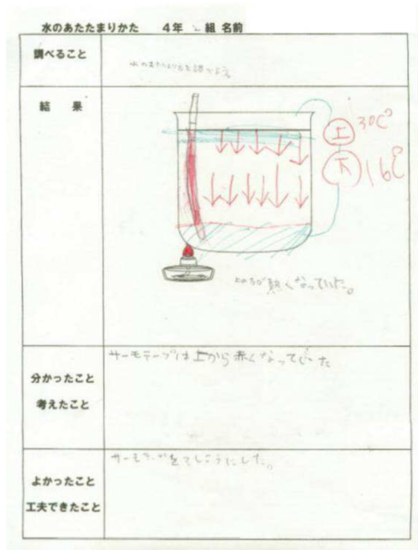
Fig. 10. Worksheets (for prediction) by Student A and Student B

Student A considered time and temperature while investigating how the water in the beaker heated up and used colour classification and arrows to clearly represent concrete predictions with diagrams and sentences. Although Student B seemed to represent temperature differences using colour classification, since there was no explanation, Student B did not sufficiently represent his prediction of how heating would occur.

When writing a prediction regarding how the water would heat up, Student A thought that the heat would be conducted in a round, circular shape, as was the case with the change of temperature on the metal plate. Student A made predictions that took time and temperature into consideration, and explained that all the water would be warm after about five minutes. When the students presented their predictions, Student A asked a friend predicting that “the entire amount will heat up after about 30 seconds” “why will it heat up after about 30 seconds?” Student A seemed to feel that explaining the reasons for his own thinking accurately and in detail would earn him praise from many friends in the class.

The goal of the third hour of this part was to have students cooperate within groups, investigate how water in a beaker heats up, and understand that water heats up through a repeated process of convection. During the experiment, by using multiple pieces of thermal tape affixed to a glass rod, the students successfully observed how the water heated up from the top. The students added substances such as sawdust, which allowed them to also observe how convection works. The demonstration experiment using a 3 L beaker made this a lesson that left a strong impression on the children. The use of a beaker of this size makes it possible to leisurely observe the state of convection, as there is a large amount of water involved. Worksheets by Student A and Student B are shown in Figure 11.





Student A	Student B

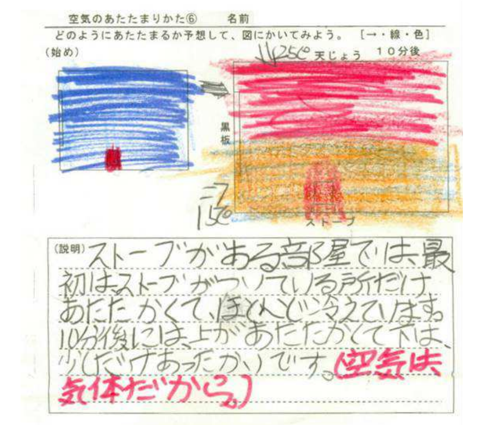
Fig. 11. Worksheets (for results) by Student A and Student B

Student A concretely recorded how the water in the beaker heated up, considering time and temperature and using colour classifications and arrows. Further, he recorded the movements of the tea leaves and the changing colours of the thermal tape. He indicated that it would take some time to heat up the water, perhaps in comparison with the experiment on the heating up of metal. Student B recorded how the water in the beaker heated up in concrete terms, considering temperature and using colour classifications and arrows. He did not record observations regarding how the substance added to the beaker moved.

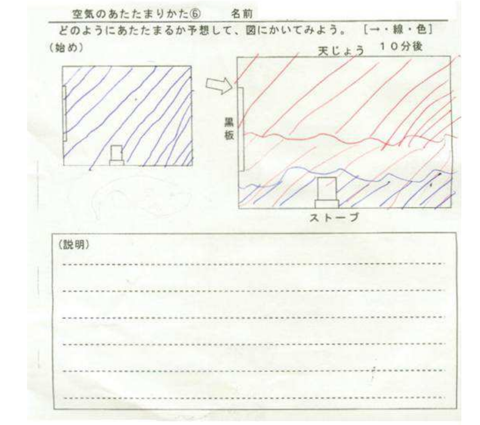
Even after the experiment started, Student A touched around the beaker in order to verify the heating with his senses, continued observations while verifying elapsed time, recorded findings on the worksheet, and otherwise participated fully in the experiment. After about seven minutes after the start of the experiment, along with changes in the thermal tape and the water, Student A also observed that the tea leaves were moving, and verified that the water was starting to heat up at the bottom. During the experiment using the 3 L beaker, Student A considered ways of improving the experimental methods by matching the experimental instruments and predicting differences in heating speed and made enthusiastic observations such as "it will take twice as long." Student A realized that water takes longer to change temperature than metal, and summarized conclusions while making comparisons with the content of previous lessons.

3.4 The fourth period of the lesson (One hour)

The goal of this lesson was to have students predict how air will heat up in a room and to make them understand that air at the heated location will move upwards, causing convection cycles to repeat as the entire room warms up. In the experiment to investigate how air heats up, the entire science room was heated with a space heater, and the resulting changes in temperature were measured. Worksheets by Student A and Student B are shown in Figure 12.



Student A



Student B

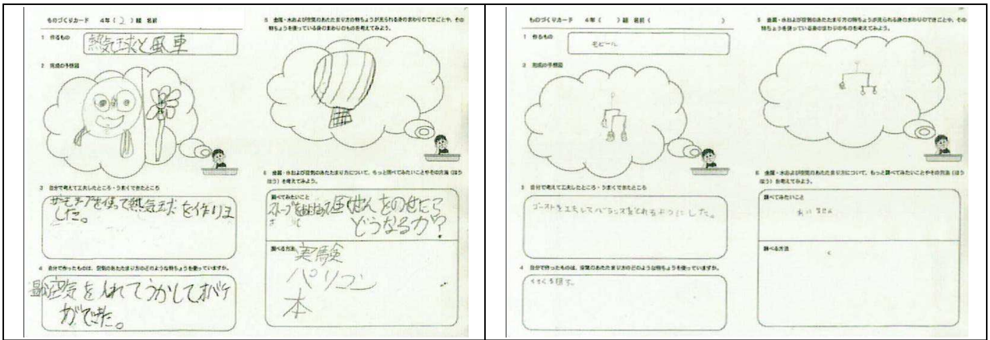
Fig. 12. Worksheets (for prediction) by Student A and Student B

Student A considered time and temperature while investigating how the air in the classroom heated up and used colour classification and arrows to clearly represent concrete predictions with diagrams and sentences. Student B used colour classifications to represent how classroom air heated up. Since there was no concrete explanation, he did not sufficiently represent predictions of how air would heat up. After the experiments, Student A properly summarized the measurement results of his group and also recorded the results of other groups. Student B was able to record the results of his own group and other groups according to temperature measurement locations. He did not summarize temperature differentials in the recording of his own group's findings.

While recording predictions, Student A used the reason "because air is a gas" to explain why the room heated up from the top. Student A based a prediction that air would heat up through convection on the previous experimental results regarding how water heats up. During the activity where the students presented their predictions, when another student stated the opinion that the room's temperature would increase to "between 18 and 62° C," Student A stated that the "room's air will not reach 62° C." During the experiment to measure room temperature, Student A stood on top of the experiment desk. While measuring the temperature of the ceiling, Student A recorded his findings on the worksheet and then compared those findings with those of other children. Not only did Student A accurately take the measurements that he was responsible for, he also did a good job cooperating while carrying out other shared responsibilities during the lesson.

3.5 The fifth period of the lesson (Two hours)

The goal of this period was to have students construct hot-air balloons, mobiles, pinwheels, and so on, that work due to air convection and to make the students understand that warm air becomes light and rises. All of the children selected and constructed an object from among the options (mobile, hot-air balloon, and pinwheel). Worksheets for designing the objects by Student A and Student B are shown in Figure 13.



Student A	Student B

Fig. 13. Worksheets (for designing the objects to make) by Student A and Student B

Student A drew two pictures of completed objects. He concretely represented everyday phenomena that could be used to investigate the characteristics of how objects heat up as well as other phenomena that he wanted to investigate further. Student B wrote about the strategy used to construct a mobile. He did not put forth any concrete examples of everyday phenomena showing the characteristics of heating that he wanted to investigate further.

Student A first selected and built a hot-air balloon. Not only did Student A start working quickly, he also finished the complete prediction diagram right away. Student A used scissors to remove the corners and taped the balloon together with cellophane tape while working very hard to construct it. Student A was interested in how the temperature of the hot-air balloon's plastic bag would rise, and immediately stuck a piece of thermal tape on the bag to try it out. In addition, Student A was the only student in the class to take on the challenge of constructing a different kind of object. When, through trial and error, Student A created a quality pinwheel within the lesson time, he looked very confident. Student A seemed to really enjoy the high level of freedom of this learning activity.

3.6 Self-evaluation and rubric assessment of the lesson

At the end of this unit's lessons, the students were asked in simple terms about the ten concrete evaluation goals, and three items were added regarding confidence, interest, and motivation regarding science in general, for a total of 13 items to be used for a self-evaluation review sheet. For each item, the students chose from "Did Well," "Did Somewhat Well," and "Could Not Do." During the point assignment part of the self-evaluation, "Did Well" items were assigned one point, "Did Somewhat Well" items were assigned two points, and "Could Not Do" items were assigned three points. The average score of self-evaluation points for each item was calculated for every student, and these averages in the class are presented along with Student A's self-evaluation scores in Figure 14. The rubric assessment of the lesson for Student A is summarized in Table 1 and Table 2.

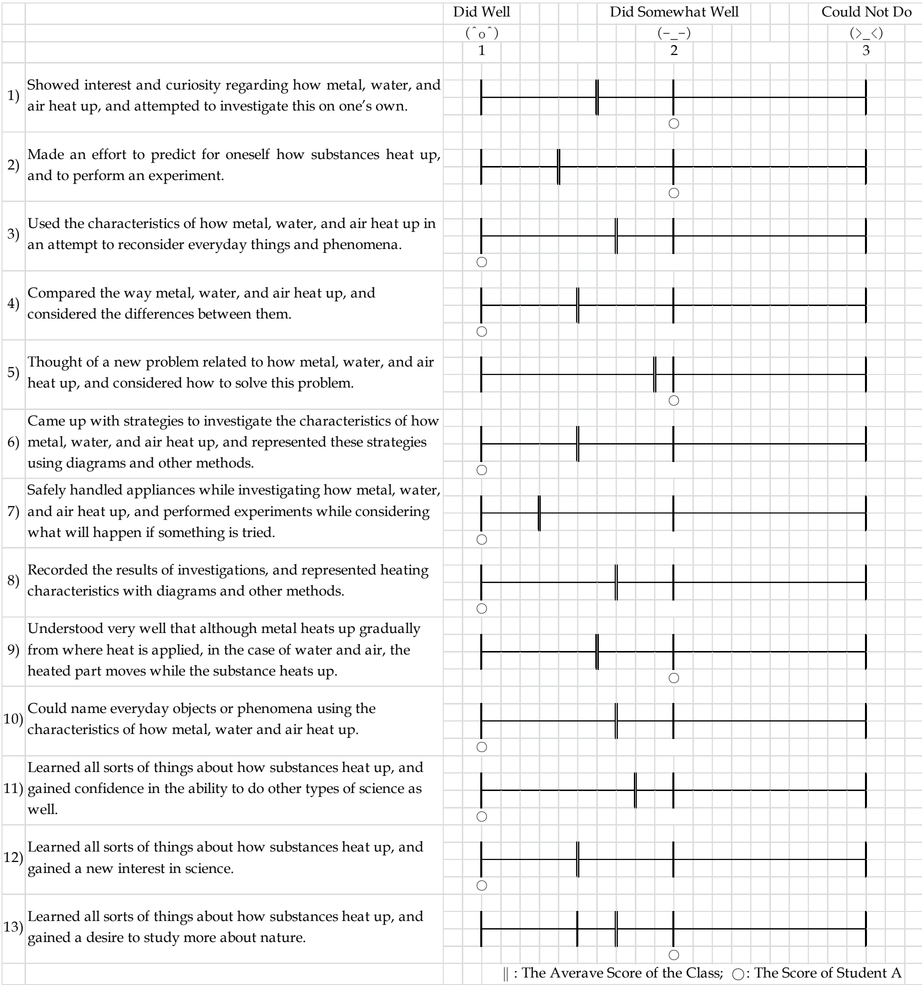


Fig. 14. The score of self-evaluation points about the lesson

Specific Evaluation Points	Evaluation Method/ Resources	Evaluation Benchmarks			Special Notes
		Fully Satisfactory	Basically Satisfactory	Needs Improvement	
Strand I: Interest, Motivation, and Attitude					
I. Shows interest and curiosity regarding how metal, water, and air heat up, and proactively attempts to investigate the differences between how these substances heat up.	Recording Analysis Behavioural Observation Remarks	Shows interest and curiosity regarding how metal, water, and air heat up, and attempts to investigate this on one's own, even outside the lesson.	Shows interest and curiosity regarding how metal, water, and air heat up, and attempts to investigate this on one's own.	Shows interest and curiosity regarding how metal, water, and air heat up, but does not attempt to investigate this on one's own.	
II. Performs experiments to investigate the characteristics of how substances heat up based on one's own predictions.	Recording Analysis Remarks	Makes an effort to clearly predict for oneself how substances heat up and to perform an experiment.	Makes an effort to predict how substances heat up, and to perform an experiment.	Attempts to perform an experiment without predicting how substances heat up.	Considers time and temperature and makes clear predictions while skilfully using diagrams.
III. Applies the characteristics of how objects heat up in an attempt to reconsider everyday things and phenomena.	Recording Analysis Behavioural Observation Works	Applies the characteristics of how metal, water, and air heat up in an attempt to reconsider everyday things and phenomena.	Applies the characteristics of how metal, water, and air heat up in an attempt to reconsider an everyday thing or phenomenon.	Does not apply the characteristics of how metal, water, and air heat up or attempt to reconsider everyday things or phenomena.	Was the only student in class to take on the challenge of constructing multiple objects, and succeeded in doing so.
Strand II: Thinking					
I. Compares the way metal, water, and air heat up, and can consider the differences between them.	Recording Analysis Remarks	Compares the way metal, water, and air heat up, and can consider the differences between them based on an attempt to organize multiple perspectives.	Compares the way metal, water, and air heat up, and can consider the differences between them.	Focuses on differences between the way metal, water, and air heat up, but cannot comprehend what the differences are.	
II. Applies the characteristics of how metal, water, and air heat up to think of new problems, as well as solutions to these problems.	Recording Analysis Behavioural Observation Works	Can think of a creative new problem regarding the characteristics of how metal, water, and air heat up and a concrete solution to this problem.	Can think of a new problem regarding the characteristics of how metal, water, and air heat up and a solution to this problem.	Cannot think of a new problem regarding the characteristics of how metal, water, and air heat up or a solution to this problem.	Was the first student in the class to affix thermal tape to a plastic hot-air balloon in order to investigate the temperature of the hot-air balloon when it rises.

Table 1. Rubric assessment of the lesson for Student A – Strand I and Strand II –

Specific Evaluation Points	Evaluation Method/ Resources	Evaluation Benchmarks			Special Notes
		Fully Satisfactory	Basically Satisfactory	Needs Improvement	
Strand III: Skills and Expression in Observation and Experiment					
I. Comes up with strategies to investigate the characteristics of how metal, water, and air heat up and can represent experimental devices and plans using diagrams and other methods.	Recording Analysis Behavioural Observation Remarks	Comes up with creative strategies to investigate the characteristics of how metal, water, and air heat up and can represent these strategies in concrete terms using diagrams and other methods.	Comes up with strategies to investigate the characteristics of how metal, water, and air heat up and can represent these strategies using diagrams and other methods.	Could not come up with strategies to investigate the characteristics of how metal, water, and air heat up or represent these strategies using diagrams and other methods.	
II. Can safely use heating appliances and the like, and can perform experiments with foresight regarding how metal, water and air heat up.	Behavioural Observation	Can perform experiments with foresight regarding how metal, water and air heat up, while coming up with strategies and safely handling equipment.	Can perform experiments with foresight regarding how metal, water and air heat up, while safely handling equipment.	Cannot safely handle equipment or perform experiments with foresight.	Correctly handled equipment while coming up with strategies regarding how to position the thermal tape and ice based on foresight. Also, asked the teacher about the danger of heating up a test tube.
III. Can investigate and record how metal, water and air heat up and can represent these characteristics using diagrams and other methods.	Recording Analysis Remarks	Can repeatedly investigate in order to record details and comes up with own strategies while representing characteristics using diagrams and other methods.	Can record results of investigations and represent characteristics using diagrams and other methods.	Cannot record results of investigations or represent characteristics using diagrams and other methods.	Considered time and temperature, and skilfully used colour classifications and arrows while representing experimental results.
Strand IV: Knowledge and Understanding					
I. Understands that although metal heats up gradually from where heat is applied, in the case of water and air, the heated part moves while the whole heats up.	Recording Analysis Remarks Test	Focuses on the properties of each substance while organizing and understanding differences between how metal, water, and air heat up.	Understands that although metal heats up gradually from where heat is applied, in the case of water and air, the heated part moves while the substance heats up.	Does not sufficiently understand the differences between how metal, water, and air heat up.	
II. Uses the characteristics of how metal, water, and air heat up to learn about everyday objects and phenomena.	Recording Analysis	Can name everyday objects and phenomena that match the characteristics of how metal, water, and air heat up.	Can name one everyday object or phenomenon that matches the characteristics of how metal, water, or air heats up.	Cannot recognize everyday objects or phenomena that match the characteristics of how metal, water, and air heat up.	

Table 2. Rubric assessment of the lesson for Student A – Strand III and Strand IV -

As shown in Figure 14, Table 1, and Table 2, it is evident that 2E Student A enjoyed the lesson very much, recognized his high competence and his own progress in science, and increased his self-efficacy and self-esteem through the lesson. He achieved more in all four strands than Student B did, and his score was much higher than the average for the class. The science teacher made special note of many aspects of Student A's learning that went beyond "Fully Satisfactory," as in Table 1 and Table 2.

4. Discussion

4.1 Student A's points of excellence throughout this lesson

Hannah & Shore (1995) showed that the metacognitive performance of 2E students resembled that of gifted students without disabilities more than that of learning-disabled students. When filling out the worksheets for predicting how substances would heat up, Student A considered temperature changes and how much time elapsed, while drawing complicated diagrams using colour classifications, arrows, and so on, and was able to neatly represent his detailed predictions. Student A carefully summarized observed changes, such as temperature differences between the top and bottom of the metal rod, how much the temperature changed, and so on, in detail. In addition, Student A made six predictions regarding how the metal plate or water would heat up, and each time, not only did Student A properly summarize his thoughts but when recording explanations, he was also able to describe his reasoning and expressed great confidence behind each prediction.

Student A verified the experimental methods and made new discoveries during the demonstration experiments, always standing right next to the teacher and listening while mumbling his own impressions and learning the lessons with extreme enthusiasm. Student A also eagerly participated in the group experiments and observations, proactively preparing and putting together each experiment's instruments and enjoying the process of learning.

During the construction activity, not only did Student A verify the properties of heated air by building a hot-air balloon, as soon as the hot-air balloon floated, Student A also built a pinwheel, making Student A the only student in the class to successfully construct two objects. Student A was also the first student to start affixing thermal tape to a hot-air balloon as part of an activity to verify air temperature and often thought of new problems while enthusiastically participating in activities.

4.2 Effects this lesson is thought to have had on Student A

It is necessary to change our present paradigm and go from a deficit to a growth paradigm in an inclusive education (Cline & Hegeman, 2001). This study focuses on nurturing the strengths of 2E children in science lessons. The innovation of using worksheets enabled the children to represent a variety of different ideas. The use of a variety of methods to meticulously and accurately record predictions, including those that are difficult to convey in presentations just using words, made it possible for Student A to skilfully summarize these predictions. Although Student A did not often make presentations or attempt to convey these ideas to other students, what Student A did think of when making predictions was recorded in an easy-to-understand fashion. In the self-evaluation review sheet as well, Student A scored high marks for items related to skills and expression.

Although in previous lessons, Student A was not enthusiastic during activities involving the recording of predictions or results in notes or worksheets, thanks to the use of coloured pencils to classify temperature and the summarizing of changes over time, Student A was able to concentrate on the work from the beginning to the end of the activity time.

The introduction of a variety of different experimental tools, such as glass rods with thermal tape applied, stopwatches for measuring the passage of time, and so on, inspired Student A to participate in the experiments and observations even more proactively. Student A's group spent less time preparing for the experiment than any other group, and by cooperating and sharing responsibilities with other group members, Student A was able to skilfully and accurately carry out the experiments.

4.3 Points for other teachers to keep in mind when implementing this lesson

The lessons of this unit were introduced with an activity that involved observing how a frying pan heats up. This gave the impression that it is important to enhance learning by taking advantage of the everyday experiences of children.

For children to be able to think for themselves of experimental material and methods and to come up with their own strategies, it is first necessary for the teacher to predict what will happen to a certain extent, and to research teaching materials while verifying safety. During this experiment regarding how a metal plate heats up, investigatory methods using the melting or hardening of egg whites, butter, ice, and so on were introduced. Although a variety of different substances will melt when heated, some substances also quickly start to burn, smoke, or emit a smell, and this is why sufficient prior research of teaching materials is necessary. The hot-air balloons used during the construction activity are made by sticking plastic bags together with cellophane tape or sealers, and unless they are as thin as approximately 0.01 ㎜, they will not float properly. If a thick plastic bag is used, since an extremely large balloon must be constructed, it will be necessary to find a place other than the science room for the activity. In addition, when a hair dryer was used to heat up the plastic bags, even after they expanded and grew very large, it was necessary to continue heating them up for two to five minutes before they would start floating.

Finally, when students were split into groups, it was evident that some consideration should be given to the configuration of group membership during observational experiments and other such activities. Besnoy (2006) proposes "Provide peer modelling." This approach permits 2E students to see how a fellow student might implement learning strategies. The inclusion of individual activities is effective, as was the case with the construction activity part of this unit's lessons. In addition, one student in the same group, who clashed several times with Student A during the lesson and who changed the comments for Student A on the mutual evaluation sheet from "Did Well" to "Poor" also filled in places where Student A worked hard and did well during the experiments. Student A, on the other hand, did not write very much. Vespi & Yewchuk (1992) note that while 2E students do not have extremely successful relationships with peers, these students are not rejected by peers and teachers in the same way that learning disabled students are. Although Student A did not write very much about the good points of fellow group members, through the exchange of review sheets, it is expected that the students will be able to realize their own ability to make improvements while building confidence at the same time.

5. Concluding remarks

Japan's special-needs education has added children with so-called "mild developmental disabilities" to the scope of programs, and although progress has been made in the detailed classification of disabilities as well as in theoretical, empirical, and practical certification, educational research involving finding the details of areas where these students excel has been lacking. It may be possible to closely tie research aimed at attesting to areas of excellence in children with learning difficulties with research aimed at compensating for weaknesses in gifted children. As Robinson (1999) stated, 2E students provide educators with an opportunity to examine school learning that addresses both strengths and needs. This is because some of the actions characteristic of children with learning difficulties actually overlap the actions characteristic of gifted children (e.g., Brody, 1997; Hartnett & Nelson, 2004; Leroux & Levitt-Perlman, 2000). For this reason, this research aimed at studying 2E children in science can serve as a seed that will grow into new educational research and practices to meet the diverse needs of children.

Suggestions for enriching the individual strengths and capabilities of students who either have trouble learning science or who show talent in science are summarized as proposals for lesson development below. These proposals are not just for students who tend towards 2E, but are also valid for regular students, including students who are gifted in science.

Proposal 1: When splitting students into groups for observations and experiments, base group configurations on predictions, methods, and so on, including the details and techniques involved in observations and experiments. Including individual activities is also effective.
Proposal 2: Include situations where children come up with their own methods and strategies, and choose their own tools during observations and experiments.
Proposal 3: Introduce situations where children use diagrams to represent their own thoughts and expressions.
Proposal 4: Increase the amount of time allowed for working and thinking.
Proposal 5: Include challenging problems.
Proposal 6: Include a construction activity in units when this is possible.
Proposal 7: Provide a variety of resources.
Proposal 8: Encourage and recognize diverse opinions.

Based on survey results regarding gifted styles in the area of science (Sumida, 2010), there is no significant difference between the ratios of students with and without LD/ADHD/HA in the gifted learning styles of science. In other words, when it comes to giftedness in science, the same opportunities are equally open both to students who have and do not have LD/ADHD/HA. This means that science lesson can help students realize their high potentials and provide in which they can take advantage of their abilities. Rather than including these proposals in every single lesson, it is advisable for teachers to consider incorporating the proposals where possible within a single unit, or within units where possible within a single semester, or within the learning activities of a single year. Finally, I would like to continue further researching into nurturing giftedness in science and into other areas. It is possible to achieve improvements in cross domains where children tend to stumble in terms of learning (in areas such as Japanese or arithmetic) and behaviour (in areas such as inattention, AD/HD, interpersonal relationships, and obsessiveness).

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Learning Disabilities

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Learning disability is a classification that includes several disorders in which a person has difficulty learning in a typical manner. Depending on the type and severity of the disability, interventions may be used to help the individual learn strategies that will foster future success. Some interventions can be quite simplistic, while others are intricate and complex. This book deserves a wide audience; it will be beneficial not only for teachers and parents struggling with attachment or behavior issues, but it will also benefit health care professionals and therapists working directly with special needs such as sensory integration dysfunction.