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Japanese Astronomy Curriculum in Schools and the Spatial Cognitive Ability of Elementary and Junior High School Students

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Abstract. In 1998 Japanese astronomy classes were shifted from grade 7 to grade 9, as advanced spatial cognition is required to understand astronomy. Consequently, students didn't learn astronomy from grade 5 to grade 8 because of this change. Agata [1] reported in 2004 that elementary school students had low recognition of astronomical events. However, detailed data was insufficient to consider this impact on the spatial cognition of students. The major aims of this study are as follows.
(1) To provide a comparison of the spatial cognition of elementary and junior high school students in 1985 and 2007.
(2) To study the impact based on the difference of the astronomy curriculum.

This study investigates the spatial cognition of 1968 students from grade 4 to grade 9, specifically, the relationship between the age when astronomy was learned and the understanding of the hemispherical concept, the left-right concept and the spherical concept. A paper test was used, asking what some spheres would look like in a dark room with a single bright light source.

The major results of this study are as follows.
(1) The hemispherical concept in 2007 is generally less well understood than in 1985 between grade 5 and 8.
(2) The understanding of spherical concepts does not decrease, compared to understanding of the left-right concept after students learn it.
(3) The spatial cognition improved between grades 5 and 8 although students did not learn astronomy; so other effects can be considered.
(4) At grade 9, understanding of each concept of spatial cognition in 2007 is almost the same or better than that in 1985.

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Although Agata [1] stated that science education collapsed with the revision of 1998, in this study it is considered that the shift of astronomy classes from grade 7 to 9 led to a general improvement of spatial cognitive ability.

Key Words: Hemispherical concept, left-right concept, spherical concept, Moon phases

MSC2010: 97M50, 85-01, 97G80

1. Introduction

In 1998 Japanese astronomy classes [2] were shifted from grade 7 to 9 (Table 1), as advanced spatial cognition is required to understand astronomy. Consequently, students did not learn astronomy from grade 5 to 8 because of this change. Agata [1] reported in 2004 that elementary school students had low recognition of astronomical events, such as 42% of students supporting the Ptolemaic theory and 53% of students not understanding the reason for the waxing and waning of the moon. However, detailed data was insufficient to consider this impact on the spatial cognition of students.

Table 1: Astronomy curriculum of Japanese elementary and junior high schools

	1977 (1980–1991)	**1989 (1992–2001)**	**1998 (2002–2010)**
G1	Shadow of the sun		
G2	The sun, shade and movement of the sun		
G3		The sun, shade and relationship between the sun and the Earth	The sun, shade and relationship between the sun and the Earth
G4	Shape and movement of the sun, Shape and movement of the moon		Movement of the moon, Features and movement of stars
G5	Shape and movement of stars and constellation	Movement, shape and positional relationship of the sun and the moon	
G6	Altitude of the sun and season	Features and movement of stars	
G7	Movement of the Earth, Revolution of the planet	Movement of the Earth, Revolution of the planet	
G8			
G9			Movement of stars and the Earth, Revolution of the planet

2. Aims

1) To provide a direct comparison of the spatial cognition of elementary and junior high school students in 1985 and 2007.
2) To study the impact based on the difference of the astronomy curriculum.

3. Survey target and survey time

In the 1985 survey, there were 971 participants and 997 in 2007, in the same school district, as shown in Table 2. The 1985 survey was conducted in early June. As 7th graders learned astronomy in early March, the survey of the 8th grade was conducted at about 3 months after the learning. In addition, as the 4th graders conducted learning of 'the shape and movement of the moon' in early October, the survey of the 5th grade was conducted at about eight months after learning.

Table 2: Number of participants

Survey time	*Grade*	*Boy*	*Girl*	*Total*
June 1985	G4	77	80	157
	G5	78	76	154
	G6	76	79	155
	G7	90	86	176
	G8	88	83	171
	G9	77	81	158
	Total	486	485	971
March 2007	G4	87	96	183
	G5	87	86	173
	G6	99	93	192
	G7	89	70	159
	G8	74	62	136
	G9	82	72	154
	Total	518	479	997

On the other hand, the 2007 survey was conducted in early March. The survey of the 9th grade was conducted at about three months after learning astronomy. The survey of the 4th grade was conducted at about 8 months after the learning of 'movement of the moon'. There were no subjects excluded from the analysis.

4. Method

A test (Figure 1) was conducted, asking what the sphere at the positions 1 − 8 would look like (Question 1: passive view), and asking what the sphere at position x would look like (Question 2: active view) in 1985 [3] and 2007 [4, 5]. Each sphere in the positions 1 − 8 (Figure 2 has a shadowed hemisphere opposite to the direction from which light comes. When this concept is understood, the hemispherical concept is defined as having been formed. Furthermore, when viewed from the center position X, the shadow on the sphere at position 5 is reversed when compared to viewing the sphere at position 1. When this concept is understood, the left-right concept is defined as having been formed.

When the sphere is viewed in positions 2 or 8, as in Figure 3, the light-dark boundary appears to be a curve. When this is understood, the spherical concept is defined as having been formed.

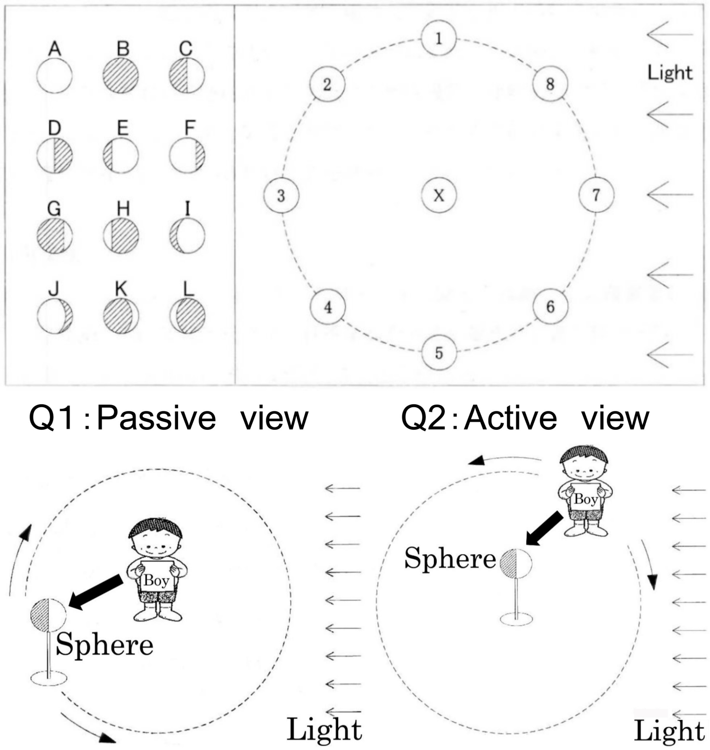


Figure 1: Paper test

5. Results and discussion

In Question 2 of the paper test in Figure 1, the sphere is fixed at the position of X. In Question 2 it is easier to understand how the leftťhemisphere becomes shaded than Question 1. Therefore, this paper is mainly based on the survey results of Question 2. That is the observer's viewing direction on the page in the hemispheric concept of 0° (Question 2, position 5), in the left-right concept of 180° (Question 2, position 1) and in the spherical concept of 45° (Question 2, position 6) from the respondent's viewing direction. The details are shown below.

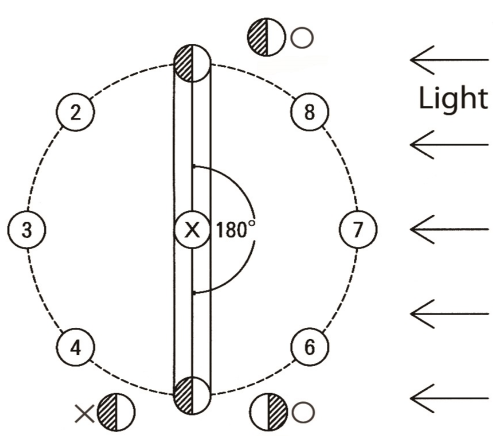


Figure 2: Hemispherical concept and left -right concept (○: correct, ×: incorrect)

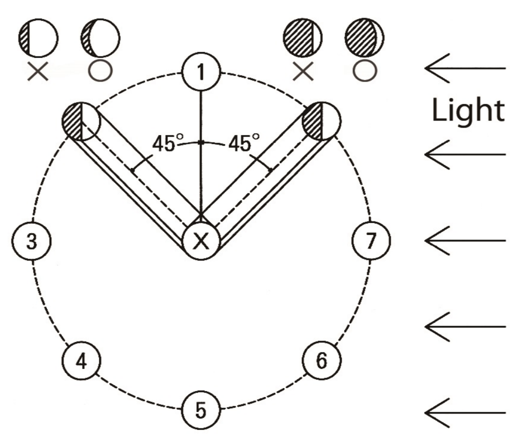
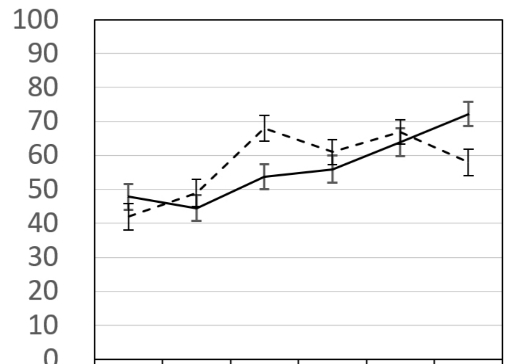


Figure 3: Spherical concept (○: correct, ×: incorrect)

5.1. Hemispherical concept

To examine the hemispherical concept, the change was compared in the correct answer rate of position 5 in Question 2 (same direction as seen by the observer respondent). The results are shown in Figure 4.



	G4	G5	G6	G7	G8	G9
—— 2007	48	44	54	56	64	72
---- 1985	42	49	68	61	67	58

Figure 4: Retention rate of hemispherical concept; error bars represent the range of ± standard error; the same below.

Even though it is the simplest problem, students who chose the correct answer were 60% in 1985 for 9th graders, about 70% in 2007. Also, in 1985, the percentage of correct answers rose from 4th grade to 6th grade. And after that, it decreased and rose repeatedly. Meanwhile, in 2007, after the rate of correct answers dropped in the 5th grade, it consistently increased until the 9th grade. Therefore, this trend will be considered statistically. A two factor analysis of variance using inverse sinusoid transformation on the correct answer rate of position 5 was conducted using the survey time (1985 and 2007) and the grade level (4th grade to 9th grade) as independent variables.

As a result, the main effect of the grade was significant ($\chi^2_{(5)} = 51.00,\ p < .01$). Also, since the interaction between the survey time and the grade was significant ($\chi^2_{(5)} = 13.18,\ p < .05$), the difference between the correct answer rates was tested (Sidak method with higher detection power than the Bonferroni method was used for the adjustment of the significance level, the same shall apply hereinafter). In 1985, since the investigation time was early June, the learning effect of the astronomical unit appeared in the next grade, and in 2007 the learning effect of the astronomical unit appears in the learned grade because the investigation time was early March. Considering the difference in the survey month, in 1985 it was revealed that the rate of correct answers was significantly higher in the 6th grade and the 8th grade in elementary school fifth graders ($p < .01$; $p < .05$). Meanwhile, in 2007, it was revealed that the correct answer rate of the junior high school 3rd grader was significantly higher than the correct answer rate of the 4th graders in elementary school ($p < .01$). In addition, when comparing the same grade in 1985 and 2007, there was a significant difference in the correct answer rate for only the 6th grade elementary school students ($p < .01$).

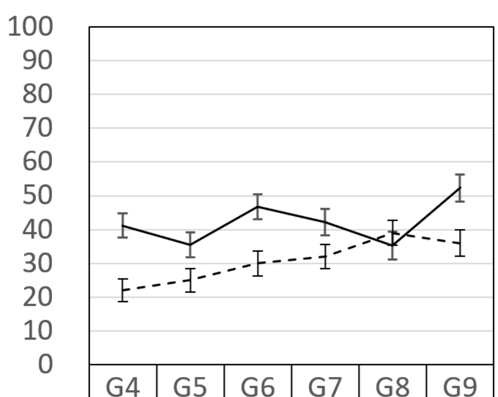
From the above, it is conceivable that in 1985, learning effects such as ‘shape and movement of stars and constellations’ in elementary school 5th graders, and ‘movement of the earth, revolution of the planet’ of 7th grader are considered. On the other hand, in learning such as the 6th grade student's 'height of the sun and the length of the shadow of the season' it seems that it did not lead to an improvement of the hemispherical concept, i.e., that it looks like a half moon if light is applied from the side. In 2007, although the outstanding effects of individual learning contents can't be read, it can be said that the rate of correct answers since the 6th grade consistently rose.

5.2. Left-right concept

In 1985, the percentage of correct answers consistently increased from the 4th grade to the 8th grade, and decreased slightly in the 9th grade (Figure 5). 8th graders with the highest percentage of correct answers were also about 40%. In 2007, the correct answer rate of only the 6th grade and 9th grade increased, and the upward and downward fluctuations were repeated. Therefore, in order to examine this tendency statistically, a two factor analysis of variance, using the inverse sine transformation on the correct answer rate in Figure 5 was performed. As a result, the survey time and the main effect of the grade were significant ($\chi^2_{(1)} = 24.30,\ p < .01;\ \chi^2_{(5)} = 15.50,\ p < .01$).

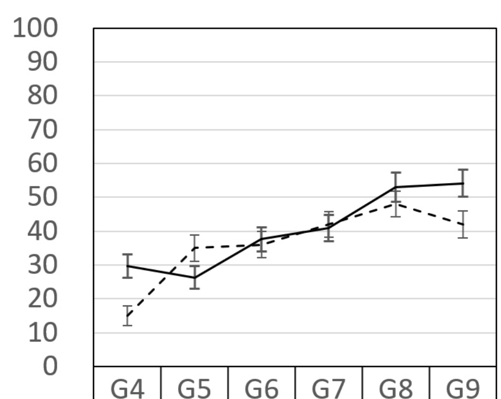
On the other hand, there was no interaction between survey time and grade ($\chi^2_{(5)} = 10.99$, n.s.). The difference in correct answer rate, there was a significant increase only between the 4th grade and the 8th grade in 1985 ($p < .01$). In addition, when comparing the same grade in 1985 and 2007, significant differences were seen in 4th graders, 5th graders, 6th graders, and 9th graders ($p < .01;\ p < .05;\ p < .01;\ p < .05$).

From the above, it can be said that in 1985, the percentage of correct answers increased from the 4th grade to the 8th grade. On the other hand, although there was no consistent trend in 2007, the effect of learning such as the 4th grader's 'movement of the moon' and the 9th grade 'celestial movements and the rotation and revolution of the earth, revolution of the planet' can be considered. Although there was no statistically significant difference, in 2007, there was a tendency for the percentage of correct answers to fall in grades not having learned astronomy (except for 6th grade students). For the left-right concept, as measured in 1985, the percentage of correct answers is highest for grade 8, as a result of learning done in grade 7. On the other hand, the percentage of correct answers in 2007 is higher in grade 4 than in 1985, and that of grades 5–9 has a generally flat trend.



	G4	G5	G6	G7	G8	G9
—— 2007	41	35	47	42	35	52
- - - - 1985	22	25	30	32	39	36

Figure 5: Retention rate of left-right concept



	G4	G5	G6	G7	G8	G9
—— 2007	30	26	38	41	53	54
- - - - 1985	15	35	36	42	48	42

Figure 6: Retention rate of spherical concept

5.3. Spherical concept

In 1985, the percentage of correct answers consistently increased from the 4th grade to the 8th grade, and decreased slightly in the 9th grade (Figure 6). In 2007, although the percentage of correct answers as a whole rose, it declined with 5th graders. Therefore, in order to examine this tendency statistically, a two factors analysis of variance using inverse sinusoid transformation on the correct answer rate in Figure 5 was performed in the same framework as in the previous section.

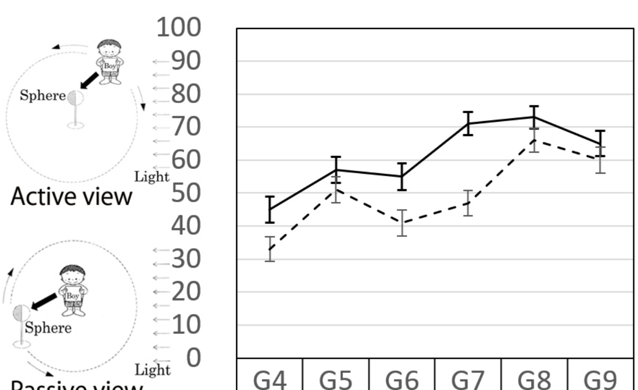
As a result, the main effect of the grade was significant ($\chi^2_{(5)} = 79.40$, $p < .01$). In addition, because the interaction between the survey time and the grade was significant ($\chi^2_{(5)} = 14.70$, $p < .05$), the difference in the correct answer rate was tested. As in the previous section, in 1985 it was revealed that the percentage of correct answers for the 4th grade was significantly lower than the correct answer rate of the 5th grade ($p < .01$). On the other hand, in 2007, it was revealed that the percentage of correct answers between the 8th graders and the 9th graders was significantly ($p < .01$) higher when the correct answer rate of the 4th graders was standardized. In addition, when comparing the same grade in 1985 and 2007, there was a significant difference only in the 4th grade ($p < .01$). For the spherical concept, the percentage of correct answers for grade 5 in 1985 was higher as a result of learning done in grade 4, and the percentage of correct answers was the largest for grade 8. In 2007, the percentage of correct answers was highest for grades 8 and 9. These results show that the understanding of each concept of spatial cognition is either almost the same or better in 2007 than in 1985.

5.4. Other findings

In addition, findings were obtained that can be used as a guide for the improvement of educational methods,

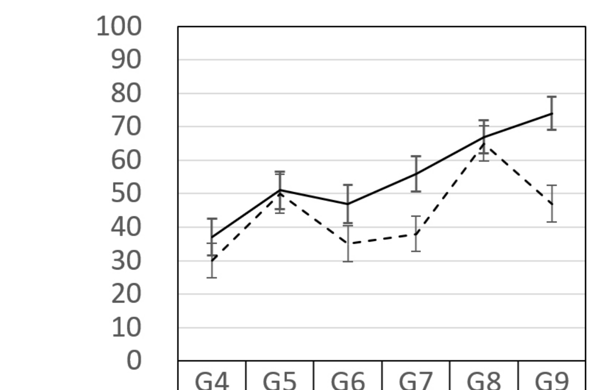
(A) viewing the focal point by moving it around (active view) is superior to viewing the focal point from one position (passive view) (Figure 7).

(B) In a one-year delayed post-test, girls showed statistically significant poorer retention of the material as compared to boys (Figure 8). The result shows that it is necessary for girls to spatially understand rather than to memorize.



	G4	G5	G6	G7	G8	G9
—— Active view	45	57	55	71	73	65
- - - - Passive view	33	51	41	47	66	60

Figure 7: Active view and passive view



	G4	G5	G6	G7	G8	G9
—— Male	37	51	47	56	67	74
- - - - Female	30	50	35	38	65	47

Figure 8: Sex differences

6. Summary of results

In order to investigate the relationship between the course of study in the field of astronomy and the formation of spatial cognition of students, the spatial cognition of elementary and junior high school students at that time in 1985 and 2007 was analyzed, and the following was revealed.

(1) The understanding of spherical concepts was greatly increased by elementary school astronomy learning. The fixation after learning was relatively good. Only in the 4th grade of elementary school, the correct answer rate was significantly higher in 2007 than in 1985.

(2) The understanding of left-right concepts was significantly higher in 2007 than in 1985 in 4th, 5th, 6th and 9th grade. On the other hand, in 2007, there was a tendency for the percentage of correct answers to decline in the grade where students did not learn astronomy.

(3) Spatial cognition gradually improved from 5th graders to 8th graders who did not learn the astronomical unit, although other influences are also conceivable.

(4) In the 1985 and 2007 surveys, about half of the 9th grade needed alternative study, in particular, active learning classes focusing on their spatial cognitive ability. Use of a 3D model and/or a discussion would be recommended for these students.

(5) Viewing the focal point by moving it around (active view) was superior to viewing the focal point from one position (passive view).

(6) In a one-year delayed post-test, girls showed statistically significant poorer retention of the material as compared to boys.

7. Conclusion and future

Although there was no statistically significant difference in the 2007 survey, the percentage of correct answers for elementary school 5th graders tended to decrease in all the four questions discussed in this paper. 4th graders were high immediately after learning of the astronomical unit, and the influence of one or more years after learning of 5th grade may be considered. Therefore, based on such findings, it is thought that it is necessary to deepen the research further on the learning and teaching method which makes spatial cognition understandable, definitely established and improved.

In Japan, drawing/craft, technology and science are taught separately in elementary and junior high schools in two subjects, but in Taiwan in one subject called “Science and Technology” in both elementary and junior high school. Since a high proportion of non-regular teachers teach technology in Japan, it is controversial whether to combine science and technology into one subject. In future studies, it is hoped to investigate what kind of curriculum is desirable in forming spatial cognitive ability. Such studies are necessary to understand elementary and junior high school students’ astronomical, geological and technology teaching materials in different curriculums in Japan, Taiwan, Mainland China, South Korea and Singapore. Furthermore, it would be useful to investigate the relationship between the spatial cognitive ability cultivated in learning individual teaching materials and the general purpose spatial cognitive ability such as the Mental Rotation Test [6, 7, 11] and the Mental Cutting Test [8, 9, 10]. Readers who are interested in such research are requested to contact the authors.

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