



# Why Do Japanese Students Have Difficulties in Astronomical and Meteorological Fields?: Reform of Teaching Methods Based on Comprehension Surveys of University and High School Students

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## Abstract

*When students are asked why they chose to take earth science courses in college liberal arts classes, many respond that they are interested in space and that they like to look at the stars. However, when we conducted a comprehension survey in class, we found that the systematic understanding of celestial bodies and weather learned in junior high school was insufficient, and that students could not explain the mechanisms of natural phenomena just by memorizing fragmentary names.*

*In addition, when students who aspire to become science teachers are asked to give a mock class in the field of astronomy and meteorology, most of them are confused because they do not know how to teach. A survey conducted by the author on college students and on junior high and high school students revealed the formation of misconceptions in the field of astronomy and meteorology, which may be caused by the compulsory education stage.*

*In the field of astronomy, students' understanding of the motion and visibility of celestial bodies such as the moon and planets, and the understanding of the motion of celestial bodies from schematic diagrams such as the diurnal and annual motion of fixed stars was particularly poor. In the class questionnaire, students stated that "this was my weak point in astronomy in junior high school," "I could not understand anything from this field," and "astronomy is a weak area of science.*

*To improve this situation, the author designed several questions based on a student misconception survey, and a teaching method in which children collaboratively explore these questions using the textbook as a tool, was found to be very effective in deep learning about celestial bodies in a junior high school class. The implementation of this method in a junior high school class has revealed that it is very effective for deep learning about celestial bodies. This time, we report on the effectiveness of this teaching method based on the results of the survey.*

**Keywords:** *misconceptions astronomy Question Design teaching method*

## 1. Student understanding of the astronomical field

When we ask students why they took an earth science class in a university course, many of them respond that they are interested in space or that they like to look at the stars. However, when classes are conducted, it has become clear that a systematic understanding of celestial bodies is in a rather serious state, and that students have only memorized fragmentary names as knowledge and have not fully developed an awareness that can explain the mechanisms of natural phenomena.

In addition, when students who want to become science teachers are asked to give mock classes in the astronomical and meteorological fields, many of them are puzzled because they do not know how to teach. A preliminary survey conducted by the author on university students and the results of the survey on junior high and high school teachers with research cooperation have revealed the formation of misconceptions in the field of astronomy and meteorology that originated in the compulsory education stage.

In the field of astronomy, students' understanding of the motion and visibility of celestial bodies such as the moon and planets, and the diurnal and annual motion of fixed stars from schematic diagrams was particularly poor, and in a class survey, students answered "I did not understand well in junior high school," "I did not understand at all from this field," and "This is my weak area of science. The author has been working on this issue since 2018.

This paper discusses the transformation of students and students by means of the teaching method developed based on the results of the analysis conducted by the author since 2018 through the "Research on the verification of the formation process of misconceptions and effective teaching methods in the field of astronomy and meteorology, focusing on the astronomical field of textbooks, and the case studies in which the author and research collaborators practiced using this teaching method. The study examined the transformation of students and pupils.



## 2.A Case Study of Misconception in the Astronomical Field

### 2.1 Understanding the planets in our solar system

A typical example is the distance between planets in the solar system. When asked "Which is farther, 'from the Earth to the Sun' or 'from the Earth to Jupiter'?" 52.7% of high school students answered that the Sun is farther (the average distance from the Earth to the Sun is 1 AU, from the Sun to Jupiter is 5 AU, and from the Earth to Jupiter is 4 times farther). This is a misconception caused by the fact that the textbooks' figures do not consider the distances of the planets in the spread and therefore do not give an image of the celestial scale of space. In order to develop a correct spatial perception of the planets in the solar system, a scale model was created by filling in the ropes with the positions of the planets that correctly reflected the distance of the planets from the sun. In this way, even if the diameter of the earth was set to 1 mm, the distance to Jupiter would be about 40 m. This helped the students to understand the image of the solar system as a planet in a deserted space.

Figure 1 is an example of the motion of Venus and its visibility that many students say they lost track of in their middle school classes. The textbook has the following diagram explaining the visibility of the inner planets, and this diagram is used to explain the visibility of Venus in position A and B respectively.

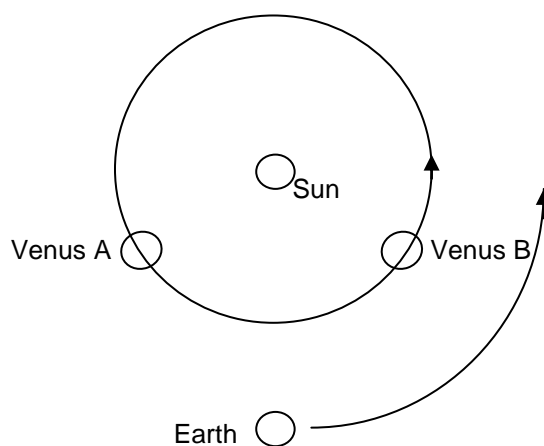


Figure 1

Using this diagram, a great many students cannot answer the question, "At what time of day and in what direction is Venus in positions A and B visible?" They are students who didn't understand it in middle school.

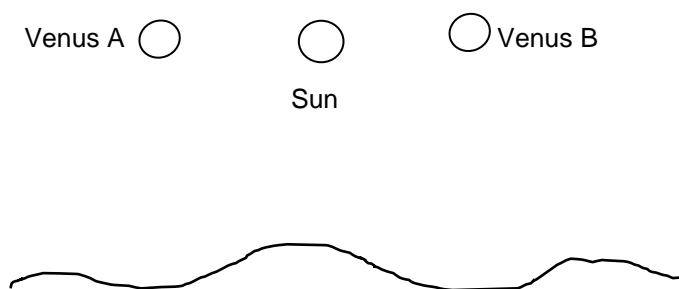


Figure 2: Image of the noon sky of the Sun and Venus at noon in the Northern Hemisphere

Therefore, the teaching method used by the author to help junior high school students understand is to "visualize the positions of the Sun and Venus in the actual sky" from the diagram in Figure 1 (Figure 2). In case A, Venus is to the left (east) of the Sun. It can be understood that "in the daytime sky, Venus is not visible to the naked eye due to the sun's light, but it is to the left of the sun, and considering the time of sunset, the sun sets in the western horizon earlier than Venus, and Venus is visible in the western sky. When we asked middle school teachers to teach this method to their students, most of them were able to understand it.



This concept is also an important perspective when considering the visibility of the moon, the earth's orbit, and the seasonal shifts in the zodiac. By reading the diagram as to whether the object in question is located to the right or left of the sun, we can understand how that object actually appears in the sky.

## 2.2 Understanding how the moon is seen

The content of moon visibility is also poorly understood. A study of textbooks reveals that both elementary and junior high schools have almost identical diagrams showing the shape of the moon and its position in the sky from crescent to waxing and waning to full moon.

The author conducted the following questionnaire on this subject.

(Number of respondents to the questionnaire: 647 high school students and 114 college students.)

The same applies to subsequent questionnaires.

Q1: One day, the moon rises around 19:00. Which of the following is correct for the moon to rise the next day? Please choose one. (The correct answer is marked with a circle.)

( ) The moon rises at an earlier time than 19:00 on the next day.

( ) The moon rises at about the same time the next day.

(○) The moon rises at least 30 minutes later than 19:00 the next day.

The percentages of correct answers were 16.1% for high school students and 19.3% for university students.

Based on these results, the author asked a similar survey of 30 people over the age of 70 to find out if this was a problem only for younger age groups. When he did so, 100% of them answered correctly. According to the Calendar Calculation Office of the National Astronomical Observatory of Japan, "Since ancient times, the moon has been called in various ways according to its phases. It appears in various waka poems and classical literature in Japan, including Manyoshu and The Tale of Genji. It is estimated that if this questionnaire were given to people in the Heian period (794-12th century), probably almost all of them would have answered correctly.

By the way, in order to transform this state of affairs into a correct scientific recognition, it is most important to carefully observe the moon as it appears in the actual sky, but it is difficult to create such opportunities. Therefore, we believe that if we change the method from "teachers teach and explain with diagrams" to "students are given questions like a questionnaire, and they think about the questions based on the diagrams in the textbooks," they should be able to arrive at the correct answers based on the diagrams in the textbooks. The diagram of the phases of the moon in any textbook shows the position and shape of the moon as seen at sunset, with the crescent moon in the western sky, the waxing moon in the southern sky, and the full moon in the eastern sky. If we only notice that the moon's position shifts more and more to the east at the same time, we can quickly get to the survey question.

## 2.3 Other results of comprehension surveys in the field of astronomy

Q2: What is a meteor? Choose one of the following that you think is correct.

(○) It is a phenomenon in which light is emitted in the upper layers of the earth's atmosphere.

( ) It is a phenomenon in which stars that make up constellations appear to move

High school students (11.9%), college students (11.4%)

( ) Bright objects are called comets because they appear to have a tail.

(Correct answers are marked with ○)

The correct answer rate was 31.2% for high school students and 38.6% for university students.

## 3 Design questions based on misconceptions of high school and college students

The following is an example of creating a question from a poorly understood content about astronomy and using the textbook as a tool for children to think about the answer to the question. The question was "Are winter constellations invisible in summer? The junior high school students challenged this question in groups while looking at the diagram in the textbook.

All groups reached the correct answer by using the method they learned in Figure 2.

In elementary school textbooks, pictures are presented as summer and winter constellations, and the class has become one in which students learn only the names of the constellations. Students are growing up without an understanding of the transitions of the constellations. Effective question design will deepen learning.

What time does the moon rise the day after a full moon? What is a meteor? If we expand to a teaching method in which students design and think about questions based on their misconceptions, the level of understanding in the astronomical field will definitely improve



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