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The four motions of the earth

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In this short letter, I would like to propose a curriculum, where four motions of the earth are properly and consciously arranged from the elementary to senior secondary levels. People who immediately recognize the four figures below are highly literate as earthlings. Earth's rotation (Figure 1) starts to relate to a science unit from Grade 3 but the topic is treated as the sun's diurnal movement and mostly by leading in the kids play of shadow. In the unit, the period given is 24 hours and defined as a day. The earth's orbit (Figure 2) causes the seasonal changes. In our country, Grade 4 students study the seasonal growth of plants with continuous observation. Also, the difference in solar altitudes due to the seasons and the change of visible night sky are learned in other grades. Considering the leap year, one year has 365.25 days. The period of rotation is 23:56 relative to the background stars, and taking into account the earth's orbit, 24 hours is redefined as a "solar day." In both cases, the point of teaching is how to transfer the students' viewpoint to the outside of the earth. Actually, the orbit is an ellipse and the sun changes its position periodically during the year but detailed explanation is avoided here.

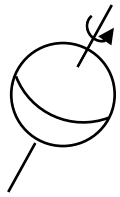

Fig.1

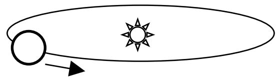

Fig.2

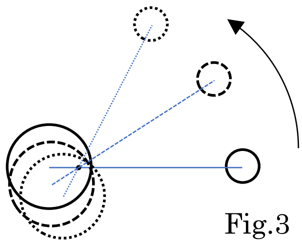

Fig.3

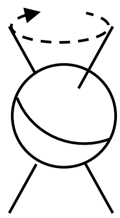

Fig.4

Recent news about some of the natural disasters in Japan may be broadcasted to your countries. Typhoon Jebi landed with a strength of 950 [hPa] in the Tokushima Prefecture at about noon on September 4 and relanded in Kobe City at around 14:00. The typhoon was characterized by a strong wind, which was recorded as the strongest wind speed in various cities. Due to the high tide, it caused serious damage to Kansai Airport. When we consider a storm surge, it is necessary to think about the drop in atmospheric pressure and the tide. The time of the high tide was 16:06 at Kobe and 17:17 at Kansai Airport Island. For every 1 [hPa] drops in pressure, the sea level increases by 1[cm]. Although it was close to the neap tide, the highest tide level, coupled with the shape of the bay and the direction of the strong winds, was recorded at the back of Osaka Bay. Thus, when we think about a storm surge or avoiding a high tide disaster, we need to consider not only the change in barometric pressure and tide levels but also strong wind and topography. This was the lesson of Typhoon Jebi.

The moon's movements are involved in the tides. Basically, we observe tidal changes in sea levels twice a day. However, many students experience difficulty in imagining these changes. The sea level close to the moon rises because of the latter's gravitational attraction. We experience a high tide when the earth's rotation moves our location on the earth's surface toward the moon (Figure 1). One of the two tides is easy to imagine. However, it is difficult for students to imagine that the sea level rises when our location moves us away from the moon. Herein, we should notice our prejudice about the Earth as the center of the moon's revolution. The earth and the moon orbit each other around a barycenter (common center of mass), which lies about 4,600 [km] from the earth's center (Figure 3). Even on the other side of the earth facing away from the moon, the sea level rises due to the centrifugal force of the earth. Not only the movement of the moon but also the movement of the earth caused the two tides a day. The moon and the earth complete one revolution relative to the stars in about 27.3 days. The tide influences all occupations, including fishing, related to the sea. In addition, the movement is similar in principle to the discovery of extrasolar planets. The existence of extrasolar planets is strongly related to the existence of extraterrestrial life, about which children are enthusiastic. Since the first extrasolar planet was discovered in 1995 by Michel Mayor from Switzerland, 3,824 more extrasolar planets (and 2,859 sun-like stars) have already been recognized. However, in school science, this content appears in earth science classes at the senior secondary level and its registration rate is only about 1 [%] in my country. Since the movement (Figure 3) is closer to our everyday life and to the development of the latest science, we should reconsider teaching the movement at a lower grade level as the third motion of the earth.

The fourth periodic movement of the earth prescribes the "one year" of all lives on the earth and it is also related to the landmark of the orientation of the North Star. The starting point of a year for all lives in the northern hemisphere is the vernal equinox. On this day, the length of the day begins to exceed the length of the night. The annual cycle of the sun from one vernal equinox to the next is called one "solar year (tropical year)," which is equal to 365.2422 days. The Gregorian calendar (365.2425 days) is also targeted for this same length. However, the earth really takes 365.2564 days to complete one full orbit around the sun with respect to the fixed stars (the sidereal year), which is longer than the solar year. Here, we can ask students what makes the difference. The preconception that the vernal equinox is immovable disturbs their minds. The vernal equinox is moving slowly every year and completes a cycle every 25,700 years. This phenomenon is caused by the fourth motion, i.e., the precession, of the earth. The ancient Greeks were aware that the motion caused the movement of the polar star. The motion is also related to the calendar, which is the basis of our lives. We should reconsider the school curriculum with a spiral structure and take into account the four movements of the earth.

At closing time, I will give you a short quiz.

What is the speed of the earth's rotation at the equator, where the radius of the earth is 6,400 [km]? (A: 1,675 [km/h] = 465 [m/s])

How fast is the earth's orbital motion when the radius of the earth's revolution (the distance to the sun) is 150 million [km]. (A: 30 [km/s])

How fast is the solar system moving in the galaxy? (A: 240 [km/s])