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A School-Made Misconception and its Cause: University Student's Misconceptions on the Formation of River Gravel in Japan

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Abstract

Children and students acquire misconceptions (naive conceptions) as they grow up. However, in some cases, misconceptions are acquired from science classes of school. As an example, we focused on the formation of river gravel. Japanese rivers are shorter and steeper than continental rivers in Europe and sometimes flow from mountains like waterfalls. Japanese science textbooks in elementary school explain that square stones flow from the upstream of the river and gradually become small round stones as they flow into the middle and downstream. To clarify the misconception of gravel formed in the Japanese river, we surveyed the misconceptions of university students that occur after learning about river gravel in Japanese elementary schools. As a result, understanding of the formation process of gravel in the river is as follows: 1. the stone upstream of river is large, the middle stream is a little small and the downstream is small like pebbles and sand as being scraped or broken. 2. The stone upstream is angular, and as it goes downstream it gradually becomes rounder. This understanding is different from the gravel actually observed. The actual shape of the gravels are as follows: 1. Not only gravels of the same size but also gravels of various sizes are present in the river. 2. The roundness of the river gravel should not be uniform in the same place. 3. The shape of the river gravel (roundness) is not determined by the distance from the upstream to downstream, but by the distance from the point where the gravel is supplied.

Keywords: *gravel, misconception, river, shape, formation, science textbook.*

1. Introduction

As children grow up, they acquire naive concepts, misconceptions that are often scientifically incorrect. Unfortunately, these naive concepts are also not easily modifiable. In science classes, it is important to turn these misconceptions into the right scientific concepts, but new misconceptions can sometimes be created in a science class at school as well, referred to as “school-made misconceptions” [1]. In this paper, one such “school-made” misconception, namely the formation process of river stone (gravel) in Japan, will be studied.

Japanese rivers differ greatly from rivers on continents such as Europe and South America. For example, the Amazon River basin area is 7.05 million km^2, while Japan’s largest river, the “Tone River,” is 18640 km^2, 420 times smaller. In the central part of Japan, there are many steep mountains on the order of 3,000 meters, and rivers in Japan are shorter and steeper than many in the world [2]. In addition, rainfall levels in Japan are twice the world average, and because its rivers cannot hold excessive water volume, it flows into the sea at once, causing a disaster.

There are also common misconceptions among the Japanese public about river stones, or gravel, found in Japanese rivers. Fifth-grade students are introduced to river stone formation through the elementary science curriculum, a part of the Japanese standard curriculum [3], where "the function of flowing water and the change of land" are described. Differences in size and shape of river stones are taught as such: “(1) To examine differences in the speed and volume of water flow, focus on the size and shape of the river stones (gravel).” In particular, the meaning of “capturing the river from upstream to downstream” might be a reflection of cultural conceptions regarding Japanese rivers passed down through the generations.

2. Purpose of study

The purpose of this study is to clarify that understanding the origin of river stone and sand is Japanese misconception and its cause.

3. Methodology

In order to gain understanding of the shape and size of the stones from upstream to downstream in the river, Japanese university students (128 students aged 20 to 21) were surveyed using a

questionnaire (Fig. 1). The questionnaire consisted of 9 questions in total, regarding changes in the shape, size, and speed of river flow from upstream to downstream (No. 1 to 5 in Fig. 1), when and from whom they learned (No. 6, 7, and 9 in Fig. 1), and an understanding of sand formation (No. 8 in Fig. 1).

Survey Questionnaire on River Stone Formation

We are investigating changes in the size and shape of river stones.

1 Circle the number you find closest to the shape of the river stone.

Upstream	squared	1	—	2	—	3	—	4	—	5	round
Midstream	squared	1	—	2	—	3	—	4	—	5	round
Downstream	squared	1	—	2	—	3	—	4	—	5	round

2 Circle the number you find closest to the size of the river stone.

Upstream	large	1	—	2	—	3	—	4	—	5	small
Midstream	large	1	—	2	—	3	—	4	—		small
Downstream	large	1	—	2	—	3	—	4	—	5	small

3 Circle the number you find closest to the speed of the river flow.

Upstream	fast	1	—	2	—	3	—	4	—	5	slow
Midstream	fast	1	—	2	—	3	—	4	—	5	slow
Downstream	fast	1	—	2	—	3	—	4	—	5	slow

4 How do river stones change size and shape as they flow from upstream to downstream?

5 Please write how you came to the reasoning in question 4, above.

6 When did you come to know or learn of the reason provided in question 4?
① before elementary school ② elementary school ③ junior high school
④ high sch0ol ⑤ no reason

7 From whom did you know or learn the above? Please answer by number.
① teacher ② mother ③ father ④ other family ⑤ book ⑥ TV
⑦ experience ⑧ other ( ) ⑨ do not know

8 Please write about how sand is mad.

9 Did what you learn in elementary school affect your thoughts on river stone formation? Please answer by number.
① Yes ② No ③ do not know

Figure 1. Survey questionnaire on river stone to students

The same survey was also conducted for an elementary school teacher (45-year-old male) and the author's family (32-year-old female, 59-year-old female, 85-year-old female, 88-year-old male).

4. Results

First, Figure 2 shows the survey results for items 1, 2, and 3 (Fig. 1).

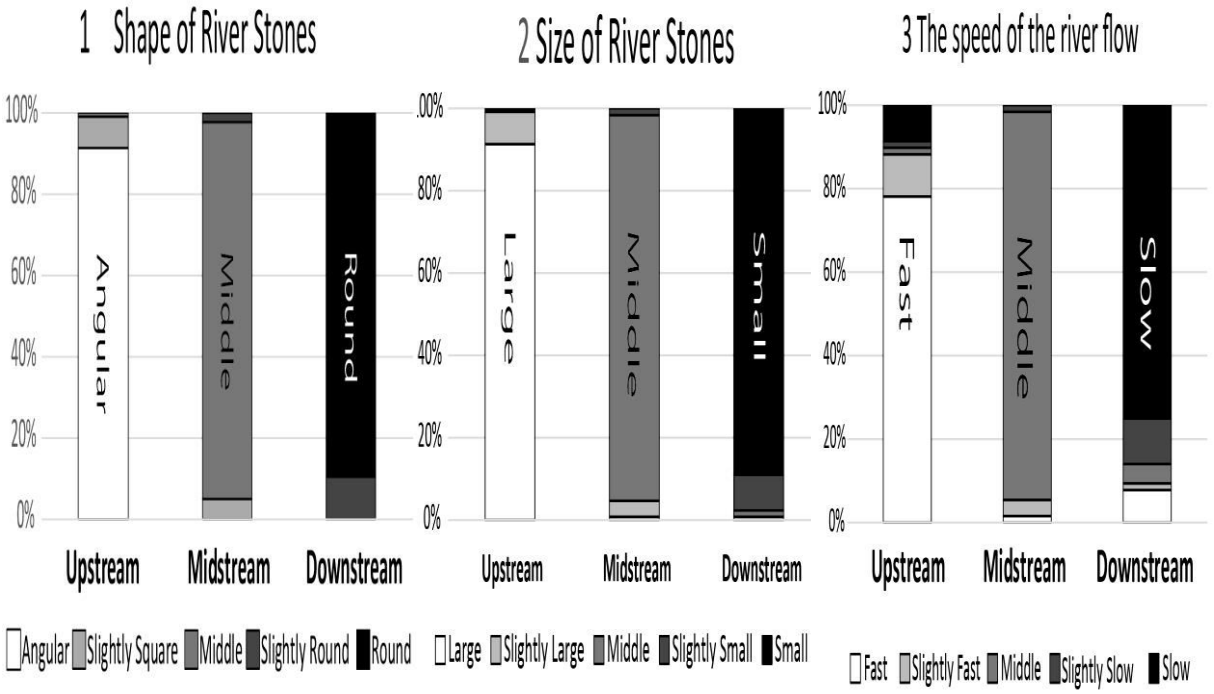

Figure 2. Diagrams: Questionnaire results for stone shape & size and speed of river flow

Figure 2 shows that students perceive river stones as angular and large upstream, middle in shape and size midstream, and round and small downstream. They believe that the speed of river flow is fast upstream, medium in the middle and slow downstream. They also report that the shape, size, and speed of the river change continuously from upstream to downstream.

Questionnaire item 4 describes how the shape and size of river stones change. As a result, “flows of the river which were large and angular in upstream flowed down, and the stones were cut by the flow of the river or other stones becoming smaller and rounder. And the shape gradually becomes rounder as the water flows downriver.” The participants provided many descriptions where the shape and size of stones change continuously from upstream to middle and downstream, supporting the results of Figure 2. In addition, the results of item 5 support item 4 as indicated by the statement "Stones collide and cut each other."

Questionnaire items 6 and 7 suggest that fifth graders (69%) in elementary school were taught and understood most of the above-mentioned conceptions, and that they learned from teachers (73%). In item 9, 55% of students thought that elementary school learning was effective regarding the above perceptions, and many indicated the major impact of elementary science classes.

Next, in item 8 regarding the formation of sand, 61.4% of the students thought that "stones would be cut down in the river and become fine and sandy," and 11.8% of students said that “stone shavings would turn into sand.” Together, 73.2% believed that “sand is formed when stones are washed down from upstream to downstream in rivers.”

Surveys of an elementary school teacher and the author's family yielded similar results. Although only one elementary school teacher was surveyed, he had almost the same understanding as university students. An elderly 85-year-old female and 88-year-old male in the family also showed the same understanding, suggesting that Japanese people of various ages may have similar perceptions of river stone formation.

5. Discussion

The general perception of Japanese people revealed in this survey is that “upstream, there are many large rugged and lumpy stones, and when descending to the middle stream they gradually become smaller and rounder as they collide with each other in the river.” And “going downstream, stones are almost uniformly cut into sand.” Next, we consider those results.

5.1 Understanding that large stones gradually become smaller from upstream to downstream

Japanese rivers have various stones of different sizes and shapes. In fact, there are many rocks and large square stones upstream, small round stones and coarse sand in the middle fan and smaller grains and sand approaching downstream. What is the cause? The formation of strata (called sedimentary facies) occurs by the change of flow velocity, resulting in the accumulation of various stones [4]. In sedimentology, the range of such velocity changes is described by the concept of "hydraulic energy" [5]. Hydraulic energy is how large the running water can carry debris particles. In fact, hydraulic energy is exerted on the river by the flow, and the speed of the flowing water can explain the erosion, transport, and accumulation of stone and sand. This force increases as flow velocity increases, while larger stones at the bottom of the river become more difficult to move. In the upstream of the river, small and light stones and sand are washed away because of the high velocity, leaving large and heavy stones. Small stones and sand roll down or float and are transported while remaining in a location that is balanced by flow velocity [6]. Thus, the differences in stone size at the upstream, midstream and downstream is not caused by "cutting corners while colliding" but by “the difference in flow velocity.” Hiroki (2019) points out that the understanding that "the size decreases as if being polished when going from upstream to downstream" is wrong. In fact, stones flow into rivers through landslides and debris flows and are subsequently transported by the speed of the stream: that is, hydraulic energy. This energy rapidly decreases and changes from upstream to downstream in Japanese rivers. Therefore, stone transported by running water becomes smaller as it goes downstream. Further, it can be explained that the upstream gravel is large, and the downstream gravel is small. However, current Japanese elementary school science textbooks explain that gravel is reduced by grinding while being transported [7].

5.2 Understanding that angular stones gradually become rounder from upstream to downstream

Next, we will examine the understanding that “from the upstream to the downstream, the angular stones are cut and polished and gradually rounded.” According to Furuta (2018), in Japanese rivers (1) the shape (degree of roundness) of the stones of on the river bed is not uniform, even in the same river. (2) Gravel flows only 3 to 4 km without turning over a long distance such as 10 km and becoming rounded. (3) The shape of gravel on the river bed (degree of roundness) is not determined by the distance from the upstream, but by the distance from the point where the gravel was supplied [8]. Certainly, it seems correct that it is washed away by flowing water and polished round. However, in rivers in Japan, stones are actually polished for only a few kilometers rather than over a long distance.

5.3 Understanding of sand formation

Next, we examine the formation of sand in rivers in Japan. Hiroki et al. (2011) suggest that more than half of elementary and junior high school students in Japan consider that sand is formed by riverbed erosion from flowing water in rivers or collision during transport of stone [9]. In this survey, 73.2% of students believed that sand is formed when rocks are washed away from upstream and downstream in rivers, with 61.4% stating that “stones were cut down in the river from upstream to downstream and became fine,” and 11.8% stating that “stone shavings became sand.” However, in fact, the sand downstream of the river cannot be reduced as stones flow down the river from upstream to downstream. Sand is originally formed by the weathering of rocks and is contained in weathered soil [9], which flows into rivers through debris flows and landslides. Thereafter, sand transported from upstream and midstream, where the flow is fast, accumulates in the downstream where the flow is slow, resulting in more sand accumulation downstream. This demonstrates that the understanding that "stone is cut from upstream to downstream and becomes sand" is a misconception.

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