Appendix: Hiramatsu's Lesson design

Teaching and Learning Plan for Grade 5 Science

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Theme: How to make students aware of the nature of balance

1. Unit name The Balance

2. Introduction

In the curriculum reform of 1999, 'The Balance' was moved from grade 4 to grade 5 and was situated as an advanced content in the unit "Leverage." Though the structure of the balance, which can measure weight, seems to be simple, it is very difficult to construct by hand. The balance is a profound educational concept for grade 5 students.

In Hiramatsu's class, most of the students made a balance as shown below. This balance stays horizontal without any weight on either plate. But it inclines to one side even with the same weight on each plate.

This phenomenon is mysterious and surprising for students because they naturally think that "After putting the same weight on both sides of a horizontally leveled balance the balance must stay level."

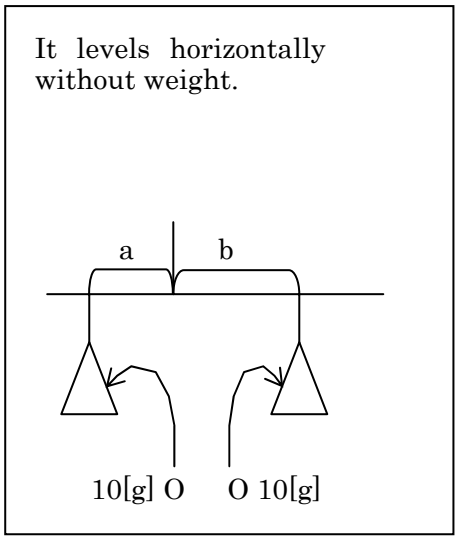
In this figure, after putting the same weight on both sides the balance inclines to the right. A mathematical explanation for this phenomenon is the following:

The length of the sides: $a < b$

After putting 10 [g] weight on each sides:

$$10a < 10b$$

Thus it is obvious why it inclines to the right.



Why do students make such balances so often? When they are making up a balance, they usually focus on the length of each arm, though they make such a balance as shown in the figure as a result. The reason lies in the material of the arm.

When students are handed out the material for making the arm, most of them put a mark at the center of the material and hang plates at the same distance from the center. If the material is homogeneous, this balance will be complete.

But even when the shape and thickness are even the arm is not always homogeneous.

The balance with its fulcrum at the center of the arm often inclines to one side. Then students make the arm horizontal by repositioning the fulcrum or the plates. This relocation makes the length of the sides different and the balance becomes one that cannot truly compare two weights. I think that the nature of teaching and learning of the balance has three components:

(1) It is an important condition for a true balance that can measure weight that its arm stays horizontal without weights added. But this condition is not enough. To help students notice this point:
(2) The true balance requires condition (1) and also the the condition that the lengths of both sides from the center are the same. To help students notice this condition:
(3) Students can make their own balances considering the two conditions above.

It is not easy to make a true balance by considering the two conditions. As mentioned above, since the material of the arm is not homogeneous the center of the arm cannot necessarily be the fulcrum. So to make up a true balance, disregarding the partial weight, the first step is to find the center of the arm by hanging it with thread and the second step is to hang same weight plates at the same distance from the center.

The textbook adopts this method of assembling a true balance without mentioning the details. But this is not the only way of assembling a true balance. It is better to help students notice that there are alternative ways of assembling as long as following the two conditions. It is desirable to cultivate such an idea as an "alternative possibility."

3. Objective

(1) Students become able to discover that a true balance which can measure weight meets two conditions (to stay horizontal without weight and to hang plates at the same distance for both sides from the center).
(2) Students become aware that the length of the thread of the plates and the position of the weight on the plate are not factors of equilibrium.
(3) Students become able to make a balance satisfying the two conditions.
(4) Students can measure weight using his/her own balance.

4. Teaching plan

Segment 1. mechanism of balance - 2 classes (today 1/2)
Segment 2. making a balance - 2 classes

Remark: This plan is only about the balance. Generally it is taught as advanced content in the leverage in grade 5.

5. Today's lesson (1)

(1) Objective To make students notice that merely leveling a balance horizontally is not sufficient for measuring weight. Also to make them able to think about the conditions of true balance in many ways.

(2) Preparation Accurate balance and inaccurate balance, 10 yen coins produced in different years, balance for laboratory use

(3) Plan for today (1/2)

Learning activity	Remarks for teaching
-- Discuss the weight of two 10 yen coins produced in different years.	-- Discuss if the two weights are the same or not? Pass them to students. Comparing them by hand is not a good idea. Then introduce the balance.
-- Discuss what happens when you put the two coins on either side of the balance made by the teacher	-- Show students a balance horizontally leveled without weights. -- Predict two cases: two 10 yen coin weights were same and different.
-- Investigate, putting two coins on the plates for each side. -- Change their position.	-- Confirm the fact that the balance inclines to one side with two 10 yen coins. -- Even changing their position, it inclines in the same way. Let students think about the reason why it inclines in many ways.
-- Help them explain their thoughts about possible causes and check each possibility. -- Cause with two weights -- Cause with different lengths of thread -- Cause with the position of coins on the plates	-- Confirm two weights are the same using a laboratory balance. -- Confirm those conditions have no relation to the balance, making two lengths of thread the same, replacing coins at different positions on the plate, etc. -- Can we make a true balance, or can't we?
-- Show another balance and put two coins on each side.	-- Confirm this balance becomes level with 10 yen coins
-- Discuss the different mechanisms of two balances.	-- Focus on the cause. Though two balances look the same at a glance, one inclines and the other is level. (Leave the question open for the next lesson.)

5. Today's lesson (2)

(1) Objective To help students notice that a true balance is level horizontally without weight and also the length of the arm for the plates from the fulcrum for each side is the same.

(2) Preparation Accurate balance and inaccurate balance, 10 yen coins produced in different years

(3) Plan for today (2/2)

Learning activity	Remarks for teaching
What is the difference between the two balances?	
-- Investigate the difference between the two types of balances handed out.	-- Wait for students to notice that the length of each side is slightly different using a ruler. -- Let students notice that the inaccurate balance inclines towards the longer arm with the same two weights.
-- conclude about the conditions of a true balance	-- Irrelevant points -- the length of the threads -- the position of the coins on the plate -- Relevant conditions -- (1) the same arm length from the fulcrum -- (2) leveled horizontally without weights
-- Let's make our own true balance considering the two conditions ! -- teacher prepares material for arm and thread -- student can bring something to make plates	-- Discuss the materials: -- what material to use for the arm, how long, etc? -- what to use for the plate and its size? -- how thick is the thread and its length? -- What to bring to school? scissors, tape, etc.
-- Premonition for next lesson	-- Produce their desire to challenge for making their own true balances.

Educational material study

1. Material for the arm

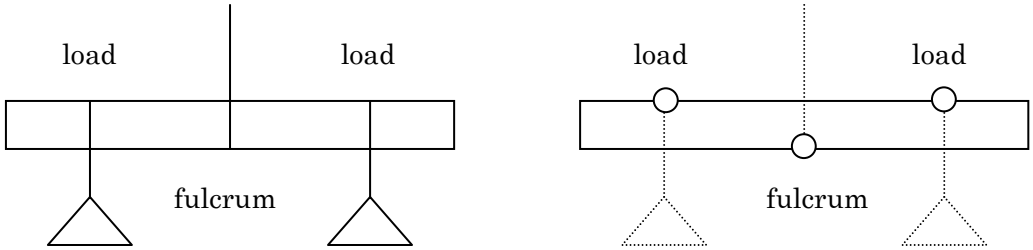
Generally the teacher cuts a wooden bar (1[cm]* 1[cm]*90[cm]) into half size and hands out to students because it is easy to make balance with certain length.

Wooden bars are not always homogeneous. The fulcrum often locates 1 or 2 [mm]

away from the center of the bar. You may see even 5 [mm] difference in an inaccurate bar. This slight inaccuracy makes it difficult for students to make up their own balance. But this can be an educational trigger. Making students focus on this little inaccuracy, they can overcome this difference and make up their own true balance. This is the value of this lesson on “balance.”

2. Thickness of the arm

Thicker material is unsuitable. Such a balance becomes unstable and it is difficult to make it accurate. The reason is shown in the following figures:



This balance is unstable because the fulcrum is situated under the arm and the loads are located on the upper side of the arm. The thicker the arm is, the higher the loads are located, the more unstable the balance becomes.

3. Making a thoughtless balance (1)

Recently, textbook companies have adopted a simple way of making a balance. Without introducing the balance above, they show a scale balance as below. Though both balances have the same function to measure weight, the former balance is much superior as an educational aid for stimulating students to think.

There is little room to think with the scale balance. Students can make the scale balance more easily because they do not need to think about the weight of the arm. But such a balance has no value to teach as advanced content in the

Figure: Scale balance

unit “Leverage”. Students have learned that they need to disregard the weight of the arm in order to apply the rule of leverage (the relationship between weight and distance from fulcrum). If making a true balance is taught in class as an advanced content, it has much more educational value.

4. Making a thoughtless balance (2)

The figure below quoted from a textbook shows making another type of balance. This balance uses a paper clip at the fulcrum. You can make this type of balance without thinking about the weight of the arm. The completed balance is quite stable or insensitive. I wonder if this is a balance or not? This is like the Japanese traditional toy, “Yajirobei.” The fulcrum of the Yajirobei is situated on the upper side of the arm compared to the loads. A lesson on making such a stable balance will be shallow and limit students’ inquiring. They may not learn the nature of the true balance. Such a Yojirobei balance is so insensitive that it may remain stable after inclining to a small degree with 1 or 2 [g] difference in the weights.

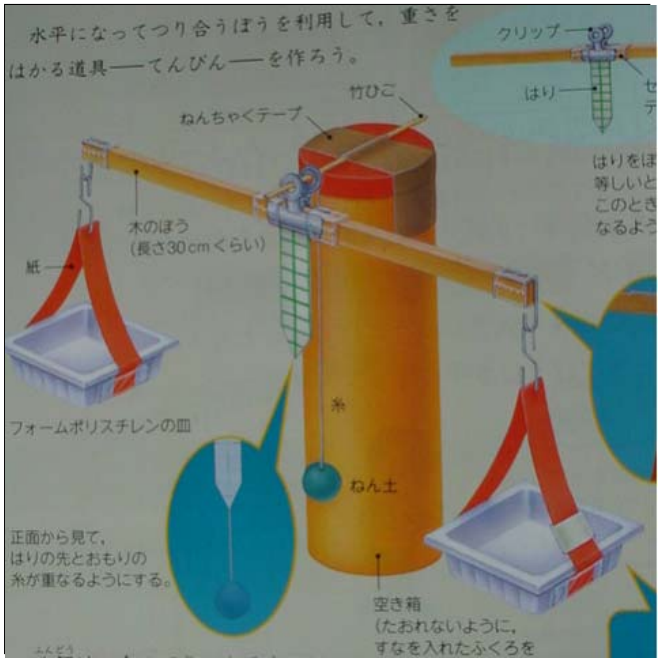


Figure: Yajirobei balance used paper clip

Homework 1

Why is such a “Yajirobei” balance insensitive?

Hint: An invisible arm exists which inclines the balance.

Homework 2

Using materials in daily life, make up your own true balance which can measure weight.