CHILDREN & BALANCES

Jos Elstgeest

Introduction

Balances are good learning aids in science education and therefore good teaching aids as well. They can be simply made so those children can work with them freely in the classroom. They give children access to same sound science. Not only do children gather some valuable information (so-called 'science fans') in the form of fundamental principles of mechanics (the inter- play between forces and movement), they also practice scientific process skills which can lead them beyond these few 'facts' into self-reliant learning and independent thinking.

The title of this chapter has been chosen with a purpose Children manipulate a balance in order to learn about some of the laws which govern its workings. The condition for learning and understanding is that the children are fully involved: by seeing for themselves, by doing things themselves, by thinking themselves, by verifying things themselves, by making mistakes themselves and by reconsidering their ideas themselves in the light of evidence which they have uncovered themselves.

The children are therefore not given answers before they have had 3 chance to ask questions. They are confronted with materials that contain a challenge that raise questions or problems, and that have possible answers within them to be released by thoughtful interaction. The children ask the balances; the balances provide the answers. The teacher helps in the asking as well as in the effort of finding an answer.

The aims of this chapter are to help teachers help children to use balances as a source of information; to 'ask the balance', using scientific process skills; and to generate, through using scientific process skills, the kind of knowledge which leads to further knowledge.

How do children use balances as a source of information?

The balance does something in response to something done to it. This makes children's observations of the working of a balance active and selective. Pushing it down and then letting it go; adding a weight to one side; removing a weight from another side; piling up weights on either side; matching weights to balance; and matching different objects to balance. All these simple actions provide active experiences, which leave behind (bits on ideas on how the balance works. The first few pages of the chapter suggest that the children do lust that. The children's active learning with balances involves thought-processes, which are expressed, quite spontaneously, by the children talking. The teacher should, with open ears, make use of this by joining in the talk, either by talking with a child individually or by leading a group discussion about what the children did and what they noticed happening. The active building-up of ideas and concepts while working, together with the co-ordinating exercise of talking about it and discussing findings, soon leads the children to make more general statements on recurring events.

It will be found, however, that younger children need much practice before they come up with (or accept) a general abstract statement, such as 'the same volumes of the same substance balance' or 'if A balances B and A balances C, then B balances C also'. Such abstractions may be clear to teachers, but children will tend to try out every instance. We should let them, for this is the way in which they form, test and use patterns.

How do children 'ask the balance'? How do they learn to apply and practice scientific process skills?

If the children just play about with balances without, somewhere along the line, being given some order and direction, they will probably make some interesting discoveries, bur learn little science, it is the teacher's task to introduce some order, or some system, into the children's work, by helping them to make the appropriate next step forward when they come to it. The discussions among the children themselves and, more so, the discussions with their teacher, provide ample opportunity to ask the right question at the right rime, or to make a suggestion for further activity in order to find more or better answer from the balance. Questions which the children ask themselves or which they adopt from their teacher are an inducement to learning and a strong motive to make an effort, to investigate, to take care to be accurate and not to give up before some understanding has been acquired.

The scientific process skills which the balances invite the children to practice are accurate observation, classifying objects, calculating, comparing quantities, manipulating materials (and instruments) deftly, some designing and making, finding patterns and relationships and, above ail, the raising of motivating questions.

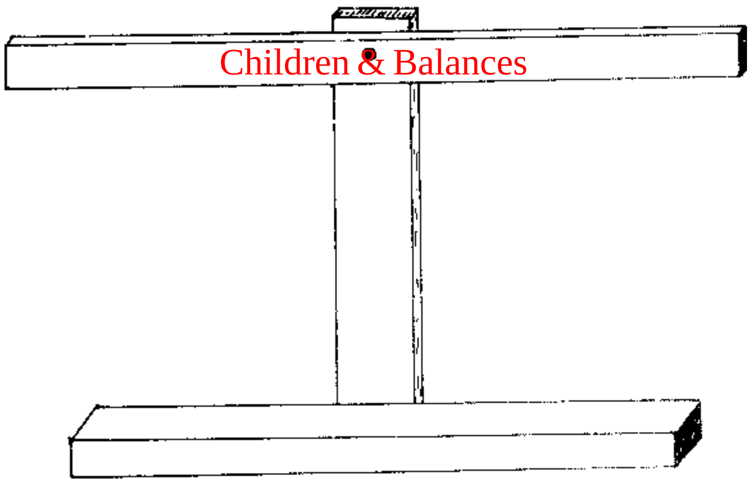
The use of these skills, made more conscious by discussion, brings order and purpose in the actions the children undertake. Creating this order and discipline in handling things creates order in the concepts, ideas and thought processes, which generate from these experiences.

How does the practice of scientific process skills lead to a kind of knowledge which generates further knowledge?

The more elaborate exercise round the question 'What makes the balance balance?', which is suggested in the text, has proven to be a powerful illustration of how science - via accurate observations and careful recording can lead to a short-cut towards learning. After having defined, some unit of weight or mass (paper clip) and a unit of distance from the fulcrum (the distance between holes in a strip of pegboard), there are a dozen or so definite simple problems to solve with the help of the balance. Confirmation of the right solution is given by the balancing balance and the outcome is systematically recorded according to the suggested scheme and outline. Invariably, someone somewhere along the activity will go beyond the simple trial-and-error approach and replace it by predicting what to do; a simple calculation is made and verified. In fact the formula 'Weight rimes distance on the left equals weight times distance on the right' (or any more sophisticated formulation of the law of moments) is being applied long before students are able to put it accurately into words. Soon a discussion develops around the question: ‘What makes a balance balance? What is in equilibrium? The units of weight or mass an either side? ‘’No.’’ Or has it to do with their position in relation to the fulcrum? ‘’Yes and no.’ Soon the proper relationship is worked out and can be expressed in words. At first the students may formulate this relationship in a rather roundabout way, but they will be able to exemplify it by using the numbers they filled in on their record. This shortens it, and from here it is only a small step towards a simple formula which corresponds with the words as well as with the figure. (Which means that the sum of the units of mass times their distance from the fulcrum on the left arm equals the sum of the units of mass times their distance from the fulcrum on the right arm.)

Provided students, or older children, have had sufficient experience and have made clear records, they can either come up themselves with, or understandingly accept, this formula or its descriptive summary. It is precisely this knowledge which generates new knowledge: new problems can now be solved the formula allows a short cut. When an unknown element is then introduced, it can be worked out by simple experimentation and calculation, as some of the exercises suggested indicate.

When the activities are carried our by student teachers, there is a double benefit. They learn or revise same fundamental principles of the physics of balances, which gives them confidence. They also analyze the scientific processes they undergo or apply, which helps them appreciate the process-based reaching which they may be asked to use in their work with children.



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A gentle word of caution in advance

A balance is an instrument to do something with.

Only by doing something with it can one investigate its working, and so begin to understand some of the laws which govern it.

Because it is an instrument for doing, it can be placed in the hands of children, and thus it will invite them to interact, that is to explore, to investigate, to experiment and so gain experience. For our primary-school children this is sufficient. Investigation turns thier minds into the fertile ground in which later understanding and more correct formulation can flourish.

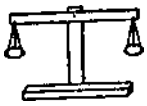
Therefore, do not force anything upon the children at first. There is nothing yet to be learned by experience. Somewhere along the line learning by heart becomes useful, perhaps, but then they will understand why, and submit to it gladly.

There are simple laws of mechanics (the interplay of forces and movement) which can be discovereed by simple investigation and experimentation. By merely manipulating simple balances children discover elementary relationships and these are all they can handle. Our abstract patterns are often beyond them. Primary-school children can manipulate things that work: balances. They have difficulty in handling our generalisations. We must give them time and opportunity to form their own generalisations out of their own experiences.

We can help them on their way by letting them work with balances, freely exploring at first, but gradually with more direction and purpose. The satisfaction of the experiences and the budding conception of what makes the balance balance, guarantee a solid foundation as a basis for reliable understanding when later abstract thinking gives meaning and coherence to observations and experiences.

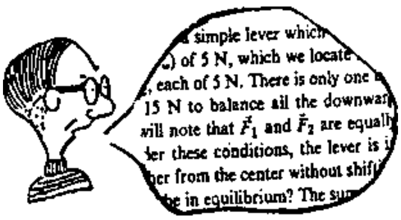
What follows is a number of ideas on how to work with children and balances. There are no 'lessons on weighing', nor is there a treatise on ' the Law of Moments'. You may add and substitute what you like, as long as it helps you to start a lively interaction between children and balances.

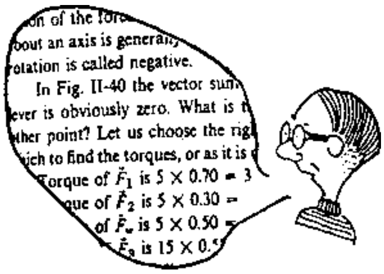
What is a balance?
What does it do?
How does it work?
How does my balance work?
How do I work with my balance?



Equal?
Equality?
Equilibrium?

Shall I ask my
teacher?





No! I think I'd better
ask my balance!

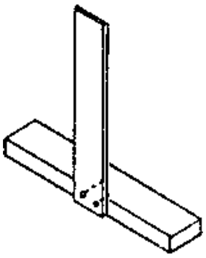
A balance is a fascinating instrument for children
to work with:

It "does" something in response to what to what
you do to it yourself.

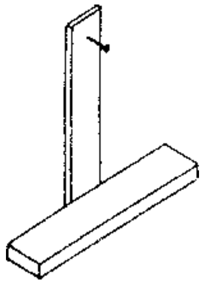
It does what I want, provided, I know what it
can do and what it is that I want.

Would you like to

ASK THE BALANCE?



Then first make a balance.
Use a
- small piece of wood
- a small slat
- a hammer and
- some nails



These drawings show how to fix things.

We can do it easily!

See that there are enough balances: At least one between two children. Working in threes is also good: it enlivens discussion.

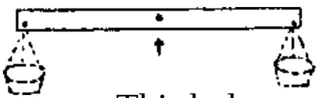
Look then!

It balances!

It doesn't

Add a strip of peg-board, two rows wide, and with an odd number of holes in each row.

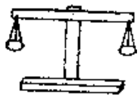
But a thin strip of wood (a slot) with a few holes makes a good balance arm, too



This hole just above the center.

Do not underestimate these very simple instruments: it is sensitive to small fractions of a gram.

With the younger children



There is little to fuss about.
Make sure that there are some balances freely available…
....together with blocks, acorns, beans, washers, and assorted odds and ends.

Let them explore as they wish:
This is a first “encounter”, leading to a first dialogue:
“What are you?”
“What can you do?”
“What do you do?”

These basic questions are sufficient for them.
Watch and learn from children and balances alike.

Look! It sits crooked.

Miss! It goes down!

First it seesaws and then it sits still.

It tilts when I take something off.

Short Story

Yulitha and Dominic are together working on the same little balance. Yulitha notices that the heavier side of the balance moves down. She adds a weight to the other side, which now moves down. Soon she is satisfied with the observation and changes to something else. Dominic, however, notices that some weights cause the arm to dip only a little way, while other weights make it swing all the way down. This fascinates him and he continues to explore this further by trying out a multitude of different objects.
This shows that not all children do the same thing when they are working on the same thing.

Making Equilibrium

Somewhat older children begin to relate the behaviour of the balance to what they put on it. They start to compare, and now their balance becomes an instrument for making equilibrium.

With nothing on it, it sits straight. I can make it sit straight with beans on it!

"Sitting straight," we call being in equilibrium.

Making equilibrium now becomes the end of the children's endeavours. They like practising this skill by making all sorts of things balance each other.

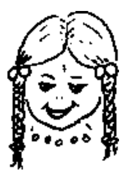
Two chestnuts are in equilibrium with five acorns.

Make equilibrium we just call balancing.

My bolt and nut will balance with seven washers.

Their trials are direct and concrete, which helps the children develop objectivity in observation. But "general rules" are not (yet) made, nor used.

Let me see what else would balance my bolt and nut?



Oh look, my bolt and nut balance my rubber!

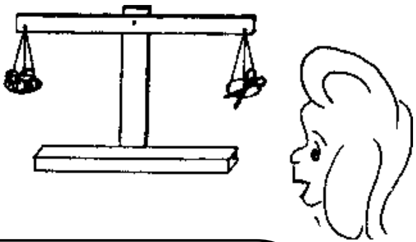
I shall try it.

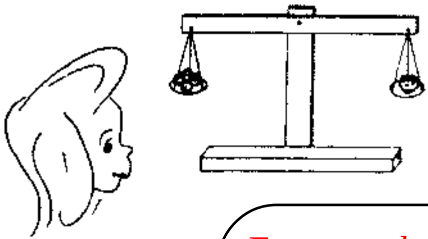
Then of course your rubber also balances seven washers.

…But that is not so obvious to this child!

From Balancing to Weighing

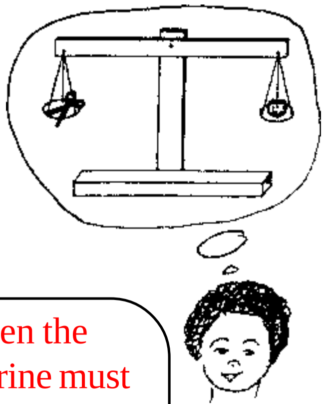
Our modern grocers no longer weigh their wares on proper balances. Instead they use some electronic gadget. Our children do not always associate weighing with balancing.





Four nuts balance a tangerine.

For nuts also balance my scissors.



I think when two things are of equal weight; they keep the balance always in equilibrium.

Then the tangerine must also balance the scissors.

Sir, where are the weights?

This, at least is true for the equal arm balance. One the children reach this notion, they can start weighing things with their simple balance.

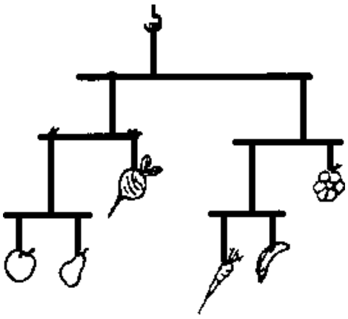
Look for your own weights. Washers are fine units of weight they'll do.

What is not a balance?

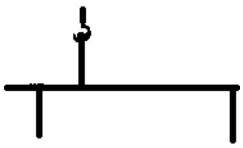
Take	a	twig
	a	knife
	a	board
	a	stick
	a	broom
	a	shoe
	a	ruler
	a	straw
	a	stiff wire
	a	spoke
	a	pencil
	a	bar of chocolate
	a	clothes hanger
	a	no matter what:

Add a piece of string in the proper position,
and you make it into a balance?

What sticks or straws, string or threads,
cut outs or things, and patience and devotion,
you can make a balance
which balances a balance
which balances a balance?

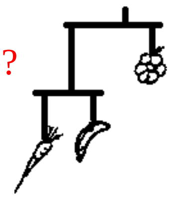


This is called a mobile.
Try making it:
With which balance will you start?

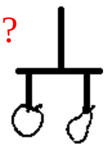


With this one?

With this one?



Or this?

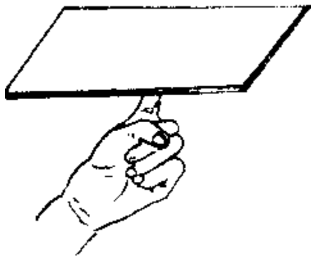


Children who can solve these little problems begin to understand quite a bit of the working of the balance.

So, why not let them do so?

Balancing Boards

Can you balance a sheet of
cardboard on the tip of your finger?



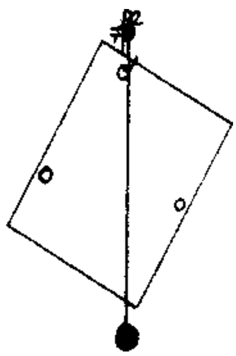
Try this:
Make a simple plumb line:
Attach a small weight to the end of
a piece of thin string or thread.
Suspend this from a hook or nail in
the wall.

- Punch 3 holes in your rectangular sheet of cardboard in three different places (The 3rd hole is a control.)

- Unbend a paperclip into a hook (twist the bottom part forward by 90-degrees)

- Hook on your cardboard and hang it behind the plumb line on the wall.

- Carefully indicate how the plumb line runs across the board.



- Repeat all this using the other two holes.

You can mark the vertical plumb line by carefully placing two dots, just underneath the weighted string. By joining the dots with pencil and ruler, you draw a good straight line.

What do these plumb lines tell you?

- What do they tell you about equilibrium?

Notice that the hole from which you suspend your cardboard is a fulcrum, a pivot, a turning point… just like the centre hole of a balance…

- How would the areas on both sides of the plumb line compare?
- Is it a matter of area?
- What is the importance of the point where the lines cross?
- From where to where do these lines run?
- Place the crossing point now on the tip of your finger….

Can you balance it on the tip of your finger?

What happens if I stick my chewing gum at the backside?

Note: the point where the lines cross in called Point of Gravity or Centre of Gravity. Could you call it "Point of Equilibrium?"

Could you find the centre of gravity…

Of a soup plate?
A shoe?
A knife?
A handkerchief?
Or your own?

Cut your card into an irregular shape. Repeat the plumb line experiment. Do the same questions apply? Stick a weight somewhere on the edge.

I am nothing but a centre of gravity!

A short story

The children on fifth grade at Vikundu, a village in the United Republic of Tanzania, worked with balances for quite some time. One of their activities was to compare various objects which they had found in and around their school, such as stones, blocks of wood, lumps of clay, dry bones, pieces of metal, fruit or inkpots. They started to arrange these things in order of weight. First they arranged them by feeling alone, without using their balance. When they later checked their "feeling" they had to make some adjustments.

These children spoke Swahili, and they used the most common word "*Uzito*" to describe literally "heaviness". The concept of "weight" as something measurable or "mass" as a physical property of substances had not yet been considered or named. Yet the problem of "heavy but small" as compared with "light but big" did arise spontaneously, first as an observation, but soon as an object of wonder and amazement. The bolt and nut (inseparably rusted together) was small but much heavier that a big dry bone. It even beat a block of wood on the balance! How is this possible?

Although solving this problem was not forced upon them, it kept their minds busy, because soon one little boy with a deep thinking furrow upon his brow declared that the "heaviness" of the iron bolt and nut must be closely packed together, closer than the "heaviness" of a bone or of wood. The bolt and the nut of smaller dimension can therefore have more "heaviness" than the bigger bone or block of wood.

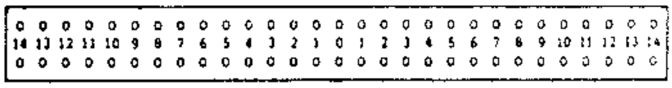
Then the boy was allowed to explain his theory to the other children and they were asked to try and find some word or expression, which would neatly describe this property. This was quite a linguistic proposition, but it set little wheels turning in their heads, and they came up with a surprisingly original term. They called it "*Uzito wa Asili*" Literally translated this means "heaviness of origin", the natural heaviness of things. What a beautiful example of trying to put an observation and its consequent concept sensibly into words! Would our "density" be so much better?

The “Law” of the balance:

Or: What makes the balance balance?

The following course of action
can be undertaken by older children.
By solving some simple, direct problems –
to which the balance ‘know’ the answers –
you are led to a general conclusion: a generalization,
a rule, and a law, which can be expressed in a formula.
(This process in called: induction)
Understanding this formula enables
you to solve new problems by deduction.

Provide enough balances with a peg-board strip as balance arm, suspended from the centre, top hole.



Number the holes as shown above. These numbers indicate the distances (D) measured from the centre (O). This is the fulcrum, or turning point.

(The number of holes may be 14, 12 or 10)

Use sturdy paper clips as “weights”, as units of mass. One paperclip is 1M. Per hole you can use more than one unit of mass: e.g. you are instructed to place “3M at D8.”

This means that you must place 3 paperclips in hole number 8 (Left or right as the case may be.)
For hanging paper clips it is better to use the holes in the bottom row of your peg-board.

Before you start, make a small rider out of bent wire, or a tiny paper clip. So that you can bring your balance arms into perfect equilibrium: only then can your balance give you faultless answers.

First of all: bring your balance to equilibrium: only the balancing balance gives you reliable answers.

 = Right  = Wrong = 

These are examples of what to do and how to record it: Put one unit of Mass at a distance 14 on the left side and 1 unit of M at D-14 on the right hand side.

This is one problem?

	Left		Right	
	M	D	M	D
	1	14	1	[14]
	[2] 2	6 4	1 [1]	[12] 8
1	1	14	2	[2]
2	2	14	1 [ ]	[ ] 4
3	[ ] 1	10 [ ]	3	11
4	3	[ ]	2	12

Mind:

What has been written MUST be done; do that first.
Then figure out what makes the balance balance …
and fill in the blanks.

	Left		Right	
	M	D	M	D
5	2	☐	☐	5
	1	9	2	[14]
6	☐	9	☐	12
	☐	7		
	☐	5		
	2	3		
7	☐	13	1	9
	3	☐	☐	☐
8	1	☐	☐	10
	2	☐	3	11
	3	5	☐	12

Now much is left to your own ingenuity; the recorded results may well differ one from the other, but if the balance is in equilibrium, the “answer” must be right.
Do you agree?

	Left		Right	
	M	D	M	D
9	3 □	5 □	□ □	13 □
10	□ 2 □	11 □ □	2	11
11	4 □	□ □	□ 1	15 □
12	□ □	□ □	□ □ □	□ □ □

No, let us take a short cut.

Ask yourself:

- When there is equilibrium?
- In what way does left equal right?
- What is the meaning of L = R?

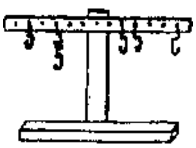
- On what does equilibrium depend?
- On the total units of mass?
- On the distance(s) of the mass(es) from the fulcrum?
Or on both?

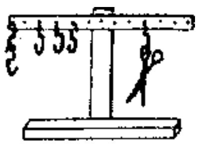
- If both M and D influence the state of equilibrium, how then are they related?

- Can you express this in a simple formula?

$$=$$

Do remember this well, because with the help of this formula and a balance you can now solve many problems that you could not solve before.





Problem 1

Use the formula to establish the "weight"
(or mass) of these scissors.
(Use the paperclip as a unit of mass).

Problem 2

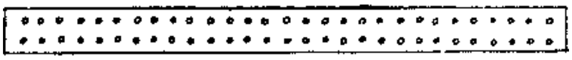
Find the "weight" (mass) of whatever you find in
- your pocket:
- knife
- pen
- comb
- lipstick
- doesn't matter what

Problem 3

Find with the help of not more than 4 paper clips
(four!) the exact mass of a ball of clay
(or plasticine)

Problem 4

What does a pin weigh?



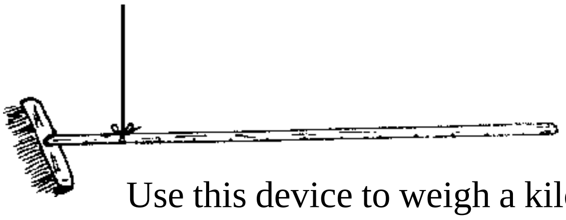
Problem 5

Establish the mass of your balance arm…

But without using another balance.

Problem 6

You have a broom and a string and a 100-gm weight…



Use this device to weigh a kilo of sugar.

End