Using toys and surprise events to teach about air and flight in the primary school

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Contents

Introduction

Most toys by their nature exhibit scientific principles in one form or another. They can be used to enliven and extend the range of science activities in the classroom, or to form the basis of interesting and enjoyable discussions between children and adults in any situation. Through their intrinsic interest and by the associations they generate, toys provide an impetus to investigation and learning through play.

The use of surprise has always been a part of the teaching and learning of science. Some of these activities are "discrepant events" which can be used to excite the curiosity of students, to challenge their ways of looking at the world, and lead on to significant concept development. The activities have also been part of an extended program of research in which I have been interested to chart students' development of science understandings across the primary school. These activities have thus been trialed both in terms of whether they 'work' but also in terms of the ideas and the learning that can come from them. I have tried to reflect that in the commentaries that go with them the ideas that students have, and the difficulties they can encounter in interpreting them. These commentaries are based on many years of experience trying these activities with both students and adults.

The questions represent ways of challenging students' understandings and focussing attention on the important features of the activity. They are not meant to be exhaustive, and it is a common experience that many more questions arise if students are allowed to explore these tricks for themselves. It is certainly intended that the surprise events are tried by the students themselves, rather than being demonstrated, but of course this can at times be impractical. Groups of students, working with these activities, generate many variations in their explorations. The activities can be seen, then, as 'taking off points', rather than as fixed menus.

For the teacher I would advise the following principles in using these activities. Firstly, in almost every case it is best for the student to do the activity themselves, or at least be active participants. In this way a richer exploration can take place. Secondly, while the intention of the activities is to promote conceptual learning, it is not the best strategy to simply tell a puzzled child 'the answer'. It is far better, in terms of learning and also enjoyment, to explore the ideas with the child, supporting their observations, pointing out features, asking questions that focus their attention on relevant features, asking them to think about their insights into other activities. In this way they can enjoy the satisfaction of exploration and intellectual achievement, and engage with their own ideas as they construct new ways of looking at the phenomena. If you simply 'tell':

- you will possibly be giving a restricted interpretation since there is often more than one way of looking at these activities.
- the child may not understand the explanation (they may 'nod', but.....) because it is not in language that is accessible to them.
- they will be robbed of the opportunity to make links with their own ideas.
- You will, over time, encourage silence in children if they feel their ideas are not valued, and they learn that the 'answer' will come if they wait.

A strategy that teachers have found very powerful with surprise events particularly is the 'predict-observe-explain' technique. Before doing an activity students are asked to predict what they think will occur, and why. This orients them to thinking about the phenomenon and makes their ideas explicit. They then observe what happens, and following that, particularly if their observation is contrary to their prediction, explain why their ideas were incorrect, and what is actually the explanation.

Air and Air Pressure

The pressure from the atmosphere gives rise to many surprising phenomena. Some of these, such as drinking through a straw, we experience so often we tend to take them for granted, or explain them in other ways.

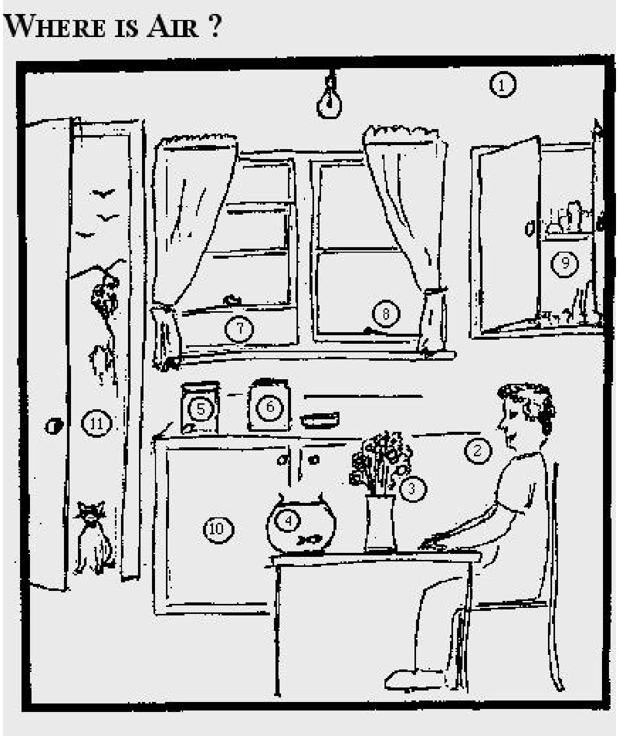
Young children find the assertion that 'air is everywhere' difficult to accept. Studies have shown that they tend to associate the presence of air mainly with open spaces, breezes and breathing, and will think, for instance, that a jar will contain no air. Some of the activities in this section are meant to reinforce the idea of air as a tangible presence, that takes up space and resists compression.

The idea that air takes up space, and competes for space with water, can be used to effectively explain most of these 'tricks'. The more powerful concept of air pressure is more difficult, but accessible in restricted form, for younger students. They tend to talk of the 'strength' of air, or of air 'pushing'.

Students tend to call up a range of conceptions to account for their observations of these activities, many of them quite useful over a range of phenomena. The idea of 'suction', for instance, while not acceptable as a scientific explanation, is more accessible to students (and adults) than the more powerful idea of competing pressures which underlies many of these tricks.

The idea of air and atmosphere is a very important to establish, since it underpins many science ideas. We have found that understandings of evaporation and the water cycle, for instance, are very dependent on the idea of a tangible atmosphere for water to evaporate into. Ideas about plant respiration, or of gas production in chemical reactions (such as between bicarbonate of soda and vinegar), depend on the idea of a gas for which air is the primary model.

Air is everywhere, and takes up space


WHERE IS AIR ?

By the age of 8 or so, most students will have a confident idea about air taking up space, and will be able to talk reasonably about some of these activities in terms of air movement, or air being squashed. However, the first few activities are quite challenging for lower primary school students.

It is instructive to talk with Grade 1 or 2 students about where air might be found; in a cupboard; a jar, or underneath the table. They can be challenged to collect air in plastic bags from places of their choice, trapping it by tying the top. Some comments:

I had no idea there would be air across the hall even though this door was shut tight.

I even found air in the toilet bowl with the door shut!

Older students might explore whether there is air in soil, or in cork, by putting them underwater and watching for bubbles. They can also measure their lung capacity by taking a deep breath, and bubbling all the air from their lungs through a plastic hose into an upturned 4 litre container held full of water in a sink full of water. The amount of air can then be measured by seeing how much water is left in the container.

Dunking a tissue

Container of water at least 15 cm deep. Glass, and box of tissues.

Push some dry tissue paper into the bottom of a glass, so that it won't fall out when the glass is upside-down.
Predict what will happen to the tissue if you push the glass, upside-down, underneath the water in the tub.
Do you think the paper will get very wet?

Take the glass out and feel the paper (**Observe**)
Can you **explain** what you find? Revisit your predictions. Were your assumptions at fault?

Commentary

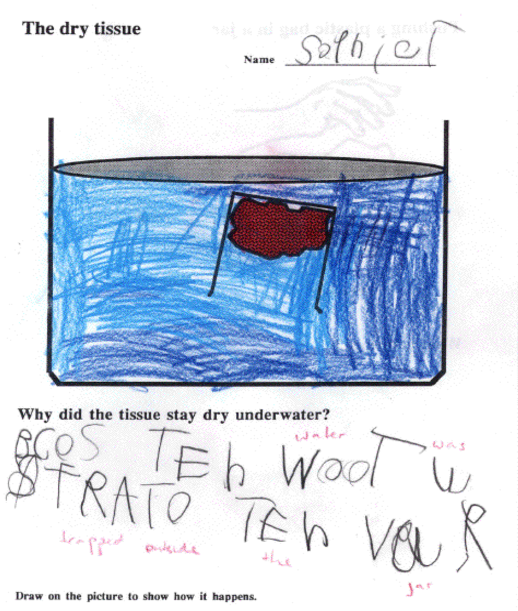
DRY TISSUE

This dunking activity is counter intuitive for students, and relies on contradicting a visual expectation that things underwater get wet. The dry tissue activity is perplexing for younger students, who might say:

- The water would get in but air gets in instead through the lip (we tried this with a beaker, which triggered this explanation that the class found quite convincing)
- It will get wet if you leave it long enough.

It is worthwhile to let students play with these activities if possible, since they will explore all sorts of possibilities. Inevitably they will get the tissue wet by putting in the beaker at an angle! That resolves the problem for some, but they can be challenged to find out how many tissues they can keep dry inside the glass.... does water come part way up into the glass? The answer is no; the air takes up its space and won't be easily compressed.
Drawing what is happening in profile gives insight into where students think the air - water surface is. The two samples of children's drawings show their different understandings.
Some students link this activity with diving bells. By age 9 or so we have found most

students can deal with explanations to these activities quite competently.


The dry tissue

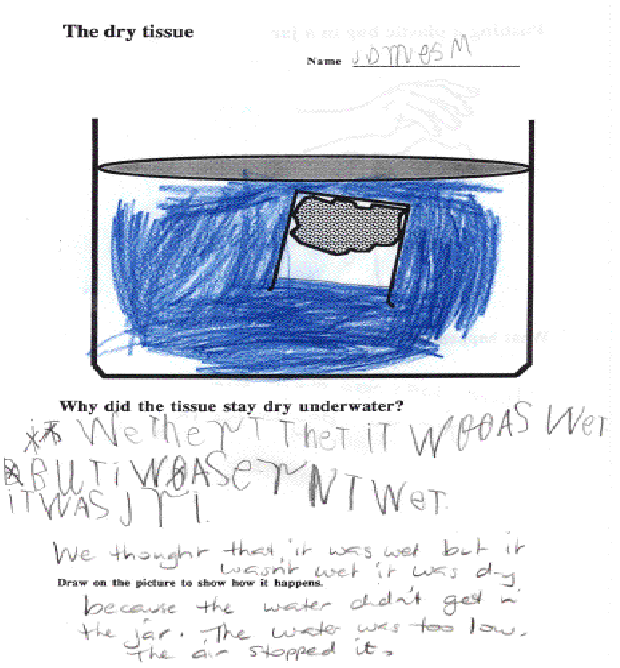
Name Sofhie

Why did the tissue stay dry underwater?

BCOS TEh WooT u
STRATO TEh VaR

water was trapped outside the jar

Draw on the picture to show how it happens.


The dry tissue

Name JOMeS M

Why did the tissue stay dry underwater?

WetheNT ThET IT WOOAS Wet
BUTiWOASeNT Wet
ITWAS JTI.

We thought that it was wet but it wasn't wet it was dry
because the water didn't get in the jar. The water was too low.
The air stopped it.

Draw on the picture to show how it happens.

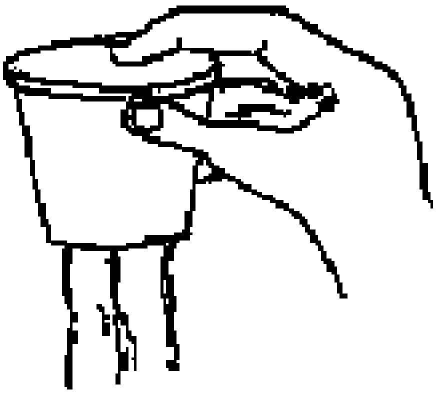
It's the atmosphere!

Activities

The magic finger

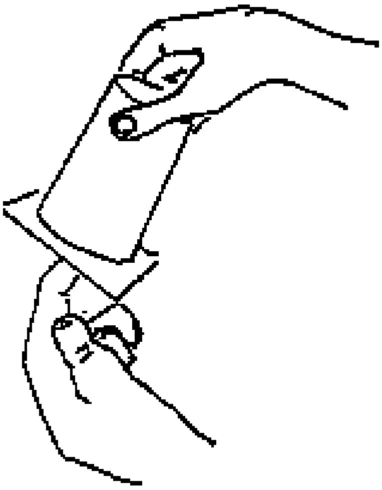
Small plastic soft drink container with screw top. Holes can be put in the bottom, and top, using a small hot nail held by pliers

A container full of water has three holes in the bottom.
What can be done to make the water come out of the holes?
Is the finger really magic?
Can you explain what is happening?
(There is a hole in the top that can be opened or closed with the finger)



The upturned glass

Glass, container to catch mistakes. Card or plastic sheet. The card should be only marginally larger than the glass.



Fill the glass with water, to the top, and put the piece of white card on top.

Hold the card while you turn the glass upside-down.

Make sure you do this over the tray, so it won't matter if it spills.

What do you think will happen if you take your finger off the card?

Does it make any difference to what happens if the glass is only half full of water?

What holds the card on?

Text books give the standard answer: "Atmospheric pressure"

But does air inside the glass play a role?

Will it work for a very tall glass?

Does it work with different liquids? Sparkling mineral water? Oil?

Is the card really needed? Lift water with a straw by putting your finger on the top of the straw. Try it with different size straws.

Does surface tension play a role? Try it with a some detergent in the water.

Commentary

The idea of atmospheric pressure is counter intuitive for two reasons - students do not have a confident idea of the gas state because they do not associate matter with an insubstantial, invisible presence. 'If you can't see it or feel it, then forget about it!' The other reason is that the effects of atmospheric pressure are mainly masked by the fact that air is everywhere. We do not collapse under the weight of the atmosphere because every part of our bodies is composed of air or water or other substances which are at atmospheric pressure and resist the effect of the atmosphere.

Another, more technical difficulty is sometimes encountered in that if students accept that the weight of the atmosphere above us is bearing down on us, they imagine the force due to this must be downwards also, and not applied in all directions, as is evident from the upturned glass or magic finger.

For all these reasons, I'd recommend saving a serious discussion of these concepts until the upper primary or lower secondary school. Nevertheless, some of these activities work well as challenges with lower year levels. Don't be disappointed, though, if they revert to simpler ideas even after you've discussed the principles thoroughly.

You will also find that students will use a variety of explanations for these activities, and will hold onto naive ideas for some despite considerable discussion. Learning is a slow process, and it's important to monitor what students are thinking about each activity.

UPTURNED GLASS

Most of these activities, involving water being supported counter intuitively, are related to the same principle. The *upturned* glass is a case in point, but I have never seen an explanation of this that is satisfactory. I've now run this activity with many students and adults, and the following questions come up:

> *How come it works with air inside... doesn't the air pressure from inside push back?*
> *Why is the card necessary? Why doesn't it work with just the water?*
> *How big a surface will the trick work with? Would it work with a bucket?*
> *How tall a glass would it work with? Surely there must be some limit?*
> *Isn't it suction? When we try to do it with no air inside, there's an air bubble that always goes up to the top, sucked up just like the card.*

The questions and extra challenges in the activity are meant to address some of these.

The reason the card stays on is because of the outside air pressure acting upwards. The complication of the air inside can be explained thus: when the glass is upturned, the water level and card drop very slightly, increasing the volume of the enclosed air. This drops the pressure, and the card settles when the upwards pressure exactly matches the downward weight of the water and card, and the downwards but reduced pressure from the air inside.

If the card is relatively rigid, you will be able to see it drops just a bit so there's a slight gap between the card and glass rim, filled with water. The surface tension of the water allows this to happen by maintaining the surface and even providing a small adhesive force. The trick works even if the water is taken out, provided the card is wet! I've found a piece of thin plastic works better than paper since it doesn't soak, but I've also done it with table napkins and glasses of wine, when pushed! You need to be careful the card or napkin is not too big so that it droops and breaks the water seal.

The trick doesn't work with lemonade because the bubbles increase the pressure inside the glass. It works without a card provided the surface is small enough to maintain the surface through cohesion, as with a straw used for transferring water by the action of the thumb at the top (identical in principle to the magic finger).

MAGIC FINGER

The magic finger is really a double trick. The original version had the magic finger on the hand not holding the container! Every time the finger points, the water comes out because, unknown to the audience, the finger on top of the (secret) hole rolls slightly to let air in. I've kept classes going on this by challenging others to see if their fingers are magic. They're always delighted to learn the trick and talk about it.

In fact even quite young students can get some sense of this activity. The easiest way to explain it is in terms of air needing to be let into the top hole to take up the space the escaping water will leave. Some students are attracted to a 'trapped/released' image and claim that the finger allows water to escaped at the bottom and air to escape out the top! The air pressure explanation involves the outside pressure pushing on the water at the holes (again, you can see the effect of surface tension as the water forms half drops) and keeping it up provided the air inside is not at atmospheric pressure also.

Flight

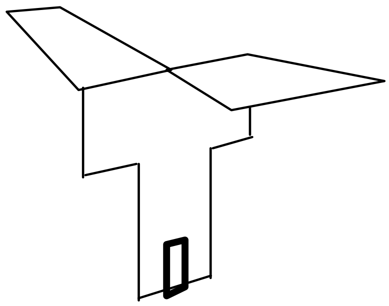
Activities

A4 sheets of paper, paper clips, tape, cotton thread, freezer bags..

Paper drop

An air resistance POE sequence. In pairs, drop:
Two sheets of A4 paper, one horizontal and one vertical
A horizontal sheet of A4 paper, compared to a crumpled sheet
A sheet, and an A4 size book
The sheet on top of the book ....the result is unexpected. What is happening?

Whirlybird



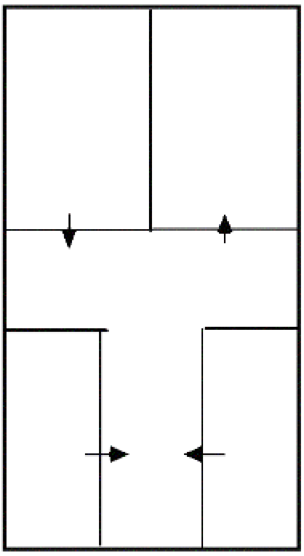
Trace and cut out the whirlybird design shown below from A4 paper. Fold it.
What do you think will happen when you drop it ? Try it.

Challenge questions :

Can you modify your whirlybird to make it spin the other way ?
Design a whirlybird that takes as long as possible to reach the ground when dropped from head high. (You might consider varying size, number of clips, wing span ....)
Design a whirlybird that spins as fast as possible.

Concept development :

What have you learnt about air flow and forces and flying, in modifying your whirlybirds ?
Develop a list of useful bits of technology based on this principle. (Windmill .....)



1. Cut along the solid lines
2. Fold along the dotted lines in the direction of the arrows
3. Place a paper clip on the bottom

Parachute

Construct a parachute using a freezer bag, or even a larger plastic bag, using cotton attached at the corners, with a plasticine model figure. Construct a parachute that will drop as slowly and steadily to the ground as possible.

Predict what will make a difference to the effectiveness of the parachute.

Try out your ideas - compare different parachutes and figure sizes and methods of attachment. It is a good idea to keep comparing your changes with a standard model.

Investigate the effect of cutting a hole in the canopy. How big a hole can be cut without ruining the parachute? What is the effect of the hole on:

the dropping speed?

the smoothness of fall?

Commentary

PAPER DROP

In the paper drop activity, most students will arrive at a conclusion that the air resists the A4 paper but that dropping it held vertically minimises the surface that is pushing through the air and hence it will drop quickly (at least initially, until it skews off course). Younger students will often say the crumpled paper drops more quickly than the A4 sheet because it is heavier. Density, or compactness, is often confused with weight, and this is a good opportunity to have that discussion. The book falls more quickly, of course. This is because it has greater weight to overcome the action of air on its surface. The real purpose of the activity, however, is the surprise and challenge offered by the fact the paper falls along with the book. The reason is that the book is pushing the air that would be resisting the paper on its own. It is not needing to force through air, and effectively falls as it would in a vacuum. I am reminded by this of the experiment conducted by Neil Armstrong on the moon, dropping a hammer and a feather to find they fall at identical rates in the absence of an atmosphere ……. as argued by Galileo. Some people argue that the paper is in the book's slipstream, which is in fact the same explanation if you think about it. The argument that air comes round the back of the book because of turbulence, and holds the paper on, is unnecessarily complicated and I think incorrect, although there is some turbulence.

I had one 5 year old child explain this counter intuitive result very quickly and convincingly by pointing out that the paper acted just like another page in the book, and so would be expected to fall with it!

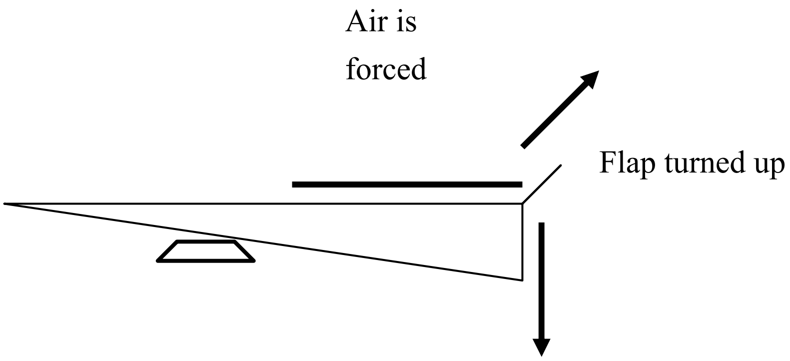
This activity can be productively extended by dropping the paper and book from a greater height - students are often convinced it would separate if given enough time - or by dropping it with the paper partly projecting out from the book. You can get some interesting turbulence / vortex effects by projecting it out a long way.

WHIRLYBIRDS

Whirlybirds are intriguing flying objects, and always cause surprise and delight for students who try them for the first time. The spinning movement is so unexpected.
The spinning effect is due to the action of air on the wings as it rushes past the dropping whirlybird. You can check this by holding the whirlybird and pushing up on one wing with your finger. The body moves back as the wing is forced up. Pushing up on the other wing has the opposite effect, and you can see that the net result is a spinning set of forces. Flipping the wings causes them to spin in the opposite direction. The longer the wings, the slower the drop because of the uplift on the greater wing area. The more paperclips, the fast the drop and spin, because of the greater weight.
The challenge of constructing a whirlybird that drops as slowly as possible is more difficult than constructing one that spins fast, although the measurement problem here is more challenging.
As well as conceptual engagement, whirlybirds provide the opportunity for the development of students' knowledge of investigations; hypothesizing, fair testing, measuring, recording and reporting. Try varying the number of paper clips, and the wing length, separately. Timing the fall is difficult, and comparing different designs two at a time is probably the most productive thing to do if you don't have access to a stop watch and a balcony from which to drop them. To keep track of what is happening, students should modify one aspect at a time, and preferably retain each modified design to keep track of what is happening.

PAPER PLANES

The same exploration principle applies to paper planes. It is instructive to keep the different models with commentaries on their flight, so that ideas can be checked and recorded. The basic principle is that air rushing past the wings provide an uplift force which counteracts the downward pull of gravity. The plane flies with the wings slightly angled up, so that air rushes faster over the top surface of the wing compared to the bottom surface, causing a pressure difference (see Bernoulli, below). The question of balance of the plane is thus important, and paper clips can help with this, generally placed towards the front. The action of the flaps in causing the plane to soar, or dive, is similar in principle to the effect of air on the whirlybird wings as shown in the diagram below of a raised flap.



The back of the plane is forced down as the air stream is forced up, thus causing the plane to lift

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