Doing what we do better than we've ever done it: Simple ideas for Enriching the Science Curriculum

Draft only : article for comment only

by Dr. Joseph Ireland "Dr Joe".

Abstract:

This article explores ways to enrich the primary and early childhood science syllabus by using practical suggestions and clear explanations of the Scientific Inquiry Skills, such as remembering, writing, sorting and listening. But science offers many more inquiry skills that add volumes to the primary science curriculum, such as questioning, observing, explaining, predicting, theorising, communicating, experimenting and much, much more. Science is a pedagogically rich subject area that has a lot to contribute to the early childhood curriculum, even moreso when the wide array of scientific 'ways of behaving' are enlisted to the cause.

Introduction

This article is written to the early childhood teacher looking for practical ideas to enrich their science curriculum. Science inquiry skills, such as remembering, writing, sorting and listening are an important part of any science curriculum. However, too often these few skills are all the science a class has! There are many important science skills that greatly add to the learning outcomes of the school curriculum, such as questioning, observing, explaining, predicting, theorising, communicating, experimenting and much, much more. These skills are a part of what it means to be "Working Scientifically". Science education has moved on quite a bit since these 'process skills' were the whole focus of what it meant to teach science, but they still play an important and vital contemporary role in science *and* in the science classroom today (Carin & Bass, 2001).

The Queensland science curriculum hosts an entire page of verbs associated with working scientifically (QSA, 1998, see appendix B). By getting to know the skills that practicing scientists use, and seeing how they can be meaningfully employed in the primary science classroom, teachers can enrich and expand the repertoire of activities that make up 'working scientifically'. More importantly, they can help students become better creators and users of scientific knowledge in the classroom and their communities.

As you read the article, I would ask you to consider these science inquiry skills and look for ways you can explicitly include them in your teaching. You may be surprised at how much good learning you already encourage is considered 'Working Scientifically'.

For example, consider the following scenario;

> *A teacher demonstrates a balloon in a bottle, and after blowing it up clicks her fingers, and it stays inflated. Students are challenged to explain their observation – is this magic, or is there a real reason the balloon won't deflate?*

Science Inquiry Skills to consider

Questioning

In science, there is probably no skill more important, nor attitude more helpful, than to encourage your students to be askers of questions. Most science begins with a question. Even those great discoveries that came about by accident did so only because someone eventually asked "What's happening here?"

Modern science education owes much to the constructivist philosophy; that learning best occurs when students are guided to construct their own understanding, and not being 'given' the right answers by teachers (Fleer & Hardy, 2001). What this can mean, among other things, is that students are always better motivated, and often learn more, when they are researching their own questions (Abruscato, 2001). Questions form a major, even key roll in real science, and have an important roll in school science (Harwood, 2004). Many modern curricular techniques are based on the teacher choosing and initiating interest in a topic, and then helping the children develop their own questions and ways of finding answers to those questions. Teachers could design an entire unit of work around questions the students have brought up. (For example, see French, 2004 or Skamp, 1998). One useful idea that is never likely to grow old is to bring a unique object to class and have the children experience it in some way, watching or touching. Then have them write all the questions they can about it (King, 2015). You can then discuss ways to find answers to the questions, or choose one to work on for a unit of work.

The best science questions are ones that we can look to find the answer to, maybe through research or an experiment of some kind. Indeed, whether an idea is testable is one measure of whether it is considered scientific (Popper, 1972, and is one of the protests against the *Intelligent Design* theory). Science questions might be "What foods do lobsters eat?" "How do ants know when it's daytime?" "Why does it rain?" Or even "Why is dirt brown?" In our example, the teacher can encourage students to ask questions about the roller: "Why does it return?", "Does its outside colour make a difference?", "What happens if you shake it?", "Does the way or direction it is rolled it effect it?", and, of course, "Why did the balloon remain inflated?"

It may seem a superfluous comment to encourage question asking when young students are so naturally curious, but sometimes we all need a reminder (and sometime, it's been so discouraged in them that they just aren't inclined to try any more). When you are faced with questions you cannot answer, please avoid "It just is". Perhaps better answers might be "We can find out!", or, "I don't know, yet." Can I also suggest; "How do you think you can find an answer to that question for yourself?" Indeed, if there is one thing teachers can do to enrich their primary science curriculum it would be to encourage students to ask more questions and think of ways to find, and test, their own answers.

Questions lead us in certain directions to look for answers, and learning to ask questions, and finding ways to answer them, is possibly the very essence of science itself. In the words of Dr Who (the Science fiction TV character), "Answers are easy, it's asking the right questions that's the trick."

Observing

We are constantly observing the world through our senses of sight, taste, touch, smell and hearing[1]. Not only can students see the roller, they can pick it up and feel its curved edges, shake it and listen to the sound, and a whole lot more. Carefully observing, and with equal care recording your observations, is an important skill in science.

However, science has a special purpose for observation; it is used *only* to say **what** you experienced, and not **why** it may have occurred. Knowing the distinction here is a difficult skill for children and adults alike. It requires suspending your explanation of what is happening: just say exactly **what** you saw/ heard/ felt etc, and not give any reason **why** things might behave as they do. For instance, you enter a room and smell a rose, but that doesn't mean there *is* a rose near by, only that you smelt one. There could be many

[1] Although, since taste and smell are both chemical reception, why not combine them into one sense? This give us the chance to add balance – without which it is more difficult to tell which way is up, or when we are changing speed and direction. Roller coasters would be a whole lot less fun without balance! Why has it never been counted as a sense? – tradition.

reasons why you smelt a rose: rose oil, perfume, hallucinations, etc. Understanding the difference between observing and explaining an observation is a challenging task!

Developing observation through senses is a great learning activity, and one that children are arguably engaged in every day. To enhance the experience, for example, teachers may set up a 'senses centre' with various activities for students to hear unique sounds, blindfolds to help feel unique objects (and 'see' them with their imaginations), and essential oils to smell unique smells. Indeed, whenever children pick up an object to explore its size, colour and shape they are observing (and perhaps that's why everything ends up in a toddler's mouth: taste, touch and smell all at once!)

Developing the skills to *report* observations is also an important skill in life and science, and important one in reporting crimes. Students could perhaps record and share their observations using pictures to show whether the day feels hot or cold, create collages to express textures, or use magazine cuts-outs to demonstrate what certain smells remind them of.

In our example; the teacher clicked their finger and the balloon remained inflated. . What was observed? The balloon remained inflated. Observations do not contain explanations, such as the balloon is sticky and was going to stay inflated for a given amount of time, or that the balloon is clearly magical and will obey the teachers every command. Say *what*, not *why*. The task of explaining why is the job of the next science skill.

You may be wondering why it is so important that students understand the skill of saying *what* they experienced, and not what it might mean or *why* it is so. This is because students and teachers often confuse ideas or explanations with sensory experience. They think they see a spider, so they decide it **was** a spider. But sensory illusions also help to illustrate that what we sense, and how we make sense of what we sense, are very different things. Only by making our observations separate from our explanations may we begin to realise our ideas are *explanations that can be tested*.

Explaining (AKA 'theorising' or 'Inference')

Explanations are attempts to give reasons for the observations. All explanations have some merit, thought the most meritorious could be said to be based on their observations and not entirely on prior or intuitive beliefs[2]. Explaining helps students explore the world with their minds as well as their senses, and is a key skill in science that might lead to the creation of theories. To encourage creative explaining, you could encourage a brain storming of ideas and explanations whenever children bring you a question, or try a think / pair / share activity to get the explaining juices flowing (Candler, 1995).

In our example, students now make suggestions as to why the balloon behaves as it does. Perhaps it has something to do with sound waves? Perhaps the bottle itself is sticky on the inside? Children are very creative in their explanations, and creativity is one of the most important attributes of great scientists (and 'more important than knowledge' in a quote attributed to Albert Einstein).

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[2] Though all explanations are, to some extent.

To further illustrate the difference between observing and inferring, for instance, a teacher walks into a room and there is a puddle of water between two children and one is holding an empty cup. One might understandably assume that they spilt the water, but this would be inferring, not observing. The observation is that there are two kids, a cup, and a puddle. But one would be wise to suspend judgement until sufficient evidence is gathered. It may turn out they found the puddle and the conscientious pair decided to try and pick it up with an empty cup[3]?

Once they have an explanation (sometimes called a 'theory'), your students might like to test it, and so we move on to the next science skill.

Predicting

This science skill is all about using our ideas or explanations of the world to predict what will happen. We can thus test our predictions to see if our explanations are supported by evidence. This is a very important way to know if we've come up with the best science ideas possible. One classic prediction experiment has students deciding whether things dropped into water will sink or float (followed by also *explaining* why they thought so.) Perhaps the children have a theory that popcorn actually pops simply because they are shaken around a lot. Is there a way to set up an experiment to test a prediction using that theory? Predicting is an important way to help children think out their consequences and the way the world works.

In our example, based on the explanation that "sound waves hit the balloon and tell it to deflate" we can test this by removing the clicking noise. Will a magic wave of the hand also work? We can test this for ourselves. Observation often pops right back in about now, as the predictions are tested as accurately and fairly as possible. You'll find that with all these aspects of working scientifically, they often interrelate and need not follow a strict linear progression.

Predictions are a powerful way to teach. Instead of using science demonstrations to prove science ideas things next time, perhaps you can stop just before you complete it and ask students to *predict what they think will happen*. Encourage them to give explanations as to why they think a certain event will occur. Then you can complete the demonstration and have them assess it in terms of their ideas. This is the basis of the Predict- Observe- Explain teaching technique of Mitchell & Mitchell (1992).

While predicting, it is vital to remind students that it is not important whether they 'get it right', but whether they learn something or not. After all, what is science? Is it about creating and testing ideas, or about learning to agree with an expert? For instance, when doing an experiment have the children predict what they think will happen. When the results are not what some children expected, point out that the goal of science is to *learn things*. Ask for hands up who learnt something (all the children whose result was not what they expected, for one), and then give a big clap to the students who learnt something because learning is what science is all about.

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[3] I share this example because it is reported to have actually happened to a teacher I visited once.

Returning to our demonstration, hopefully the students will eventually observe the teacher holding their finger over an air hole at the base of the bottle, and perhaps the students might even think of a way to test that by having the teacher hold the bottle in such a way that they cannot cover the hole. But even when they figure it out that the trick is science, not magic, the questions need not end. Students will still need to use their imagination, creativity and past experience to understand how covering up the hole keeps the balloon inflated. In short, science not only begins with questions, it ends with them too in a potentially never ending cycle of questions, answers, and experiments.

Communicating

Once students have learnt something new they have the opportunity to explain it to others. Scientists do this all the time. Students can use many different means to express their ideas. They can draw them, act them out, move their hands like the wind, imitate animal sounds with their voice, write a story about Derry the Drip and a day in the life of the water cycle. There is a large scope for creativity, and for using the arts in science, to express scientific ideas (Meador, 2003). Learning to communicate ideas clearly and informatively is a useful skill in life, and communicating ideas to others is a powerful way of helping students consolidate and monitor their own learning. Science communication traditionally, and for good reasons, also plays an important part in the summative assessment of students learning in science. (And an even larger part in the decorating of school classrooms worldwide!)

Science reports need not be boring monologues, or even structured presentations. Drawing pictures, writing songs, putting on plays for parents, and making models are all highly valid and highly motivating means of helping children communicate their learning in science. How will you get them to discuss their shared ideas of what makes the balloon stay inflated?

Two points in further depth

Theorising

Theories are like stories; explanations or models that attempt to make sense of the complex way the world operates. Theories often involve things that aren't directly observable, such as atoms or forces. Each theory implies certain predictions about the world can be made; thus we test our predictions, not our theories (since, for one reason, theories involve things that cannot be directly observed.)

Researchers such as Sandoval (2005) have been arguing for some time that science should be taught as models or theories to be tested (especially ones generated by the students themselves), and not as impersonal concepts to be demonstrated as correct. A powerful way to teach can be to have student's gather their own evidence to support or refute the explanations given in textbooks or from the teacher. (As opposed to the current practice of giving students the theories and explanations, and then the tests that supposedly 'prove' them true). Doing this can help students come to know the nature of science better, especially if you talk openly about the processes (Abd-El-Khalick and Lederman, 2000.)

If, however, students do become stuck or seem to be re-enforcing the wrong ideas, you still can choose to present the accepted scientific explanation as a theory or model for the students to *test*, as opposed to the answer they're *supposed* to be getting. For example, 'one theory that scientists often use to explain this situation is… what do you think' (Abell, Smith & Volkmann, 2004). They may disagree with the theory, but the hope is that they will at least understand it. This brings them into conversation with scientific ideas, rather than subjugation.

The important point here is that scientific knowledge need not be taken for granted. Students can and should explore scientific claims and concepts for themselves, and not simply absorb them from a text book or believe them because the teacher says so (ie, Spencer, 1864). The failure to do so may be one factor that leads to the disaffection of science learners who fail to see its usefulness in their everyday life, as opposed to becoming scientifically literate individuals who use their critical thinking skills to make valuable contributions to a knowledge driven society (Carin and Bass, 2001). Students in any science class can embrace this *scientific literacy*.

Creating and testing theories is what science is all about, and it's something students can do too. Set up some batteries, bulbs and wires, and after students manage to light them, challenge them to create, and test, a theory as to what is happening in the wires (ie, Abell, Smith and Volkman, 2004). Challenge students to explain the relationship between the length and speed of a pendulum (eg, Carin and Bass, 2001). Teaching science as theories to be explored, rather than as concepts to be memorised, is a powerful way to enrich the early childhood science curriculum.

Experimenting

Everything we have been discussing so far forms a major part of what it means to do when we are 'experimenting': questioning, observing, generating explanations, testing hypothesis, forming theories, communicating our results and questioning again (but not necessarily in that order). 'Experiments' are not the only way to do science (Lederman, 2004), but they are a very common way (for good reasons). Of course, experiments can be much more complicated things with independent variables, null hypotheses and random distributions. But there are lots of theories that you can experiment on right in your school that deal directly with the needs and experiences of the children. If someone has a theory that the moon only comes out at night (and many people do in my experience), take several days (same time every day for at least three weeks) and see if you can spot the moon during the day. Try experimenting on the theory that plants need predominantly red light for photosynthesis by growing plants in different conditions. Experiment on the theory that sedimentary rocks 'drink' because they are porous by comparing their density to igneous rocks (or observing them under a microscope). Test your ideas about how the world works, about the differences between boys and girls, even about ways to teach science better; the list goes on and on and on.

Important in experimenting (and often overlooked) is the notion of a "**fair test**". For example, is it fair to test the theory that boys are stronger then girls with grade 2 girls V's the grade 7 boys? Or just to be political, is it fair to test intelligence using tests designed in one group or culture in another culture that values different kinds of excellence? You see, a fair experiment will do things such as try to make all other conditions equal *except* the one(s) you wish to test. Consider: Is it a fair test for microbes when the agar plates from location 1 are kept in a different incubator to the agar plates from location 2? Can you be sure what you are testing, locations, or incubators…? While it may be impossible to be completely 'fair', it is something scientists, and good science students, understandably go to great lengths to try to be.

Another important point in experimenting is that of **multiple trials**, or that single examples are rarely enough to establish a knowledge claim in science. For example, imagine you and your class are trying to see which is will run a maze faster, white or black mice. How many trails does it take before you can say for sure which kind of mouse is faster? 10? 100? You decide. However, the idea is that in science that there is never enough evidence to prove a theory irrefutable beyond all doubt forever, since for one reason it is impossible to experiment on every single instance of a phenomenon (see 'Underdetermination', Kosso, 1992). Still, at some point we must decide that our results are reasonably sufficient to make a claim.

For this reason, all scientific ideas are up for review at any time, should the scientific community form consensus that a better theory has come along, or new evidence has cast doubt on the effectiveness of an older theory. This is a fundamental attribute of the nature of science (QSA, 1998.), and has been called the **tentative** nature of scientific knowledge (Also, 'reversionary' or 'subject to change', Lederman, 2004), though others prefer the term 'open minded' for philosophical reasons (Harding and Hare, 2000). Tentativeness can be a part of science teaching when students are taught that all scientific knowledge is up for review, but is currently accepted for very good reasons; reasons which are often very evidence based. Because of this, even you and your students can contribute to what science knows (with lots of hard work and careful experiments!), and certainly challenge the many inappropriate claims made in the name of science everyday.

I find it useful to discriminate between **tests** and experiments in my work, though for most practical reasons it is an unnecessary distinction. Tests are things that don't need to have a theory or prediction at all. Whenever you start a sentence with: 'Let's see what happens when …' you are doing a science test. Children, adults and even animals do these kinds of tests all the time, seeing what will happen when they do certain things. Try stacking blocks in a certain way. Hang some birdseed sticks in the garden and see what kinds of birds (and bugs) they attract. Swing a cat by it's tail (Ok, don't do that). Find out what things make shadows and the kinds of shadows that they make. Free- range testing is important in science and science education, and can lead to scientific experiments later on.

Testing can also mean using science skills and materials to learn something about specific objects and people (ie, testing for cancer, performing a scratch test in geology). The point I wish to emphasise here is unless you are investigating a theory, it will be confusing to call your activity 'experimenting'.

Also, **demonstrations** are diverse from experiments in that they involve making a point rather than testing an idea (usually by the teacher in front of the class, but it also includes most practical activities in science classes). While these demonstrations are important for science education and certainly do have their place, sadly, this seems to be most common way (and sometimes only) way that science is taught (Fleer & Hardy, 2001). To expand of this, since experiments are used to test predictions (derived from theories) most science 'experiments' in schools aren't experiments at all, but are demonstrations or 'proofs', even in high school (Goodrum, Hackling and Rennie, 2001).

Teaching predominantly in this way fails to challenge students intellectually, and makes the point of school science seem to be the generating of various simple effects (as opposed to creating and testing ideas, e.g. Schauble et al, cited in Sandoval 2005). This can give students the unfortunate impression that science and working scientifically have little to contribute to the decisions in everyday life. But they can, as Chinn and Malhotra (2002) state;

> "All citizens need to be able to reason well about complex evidence such as evidence relating to health and medical decisions, evidence relating to social policies upon which citizens vote, or evidence relating to the best way to promote employee motivation and satisfaction. Learning an oversimplified version of scientific reasoning will not help on such real-world tasks." (p 213)

It is important to note that not all sciences progress using this "Experimental method", and that this is also certainly not the only valid way to do science. For instance, Lederman (2004) cites 3 general levels of scientific inquiry; Descriptive (closely observing a situation, common to anatomy and taxonomy for instance), Correlational (comparing information for patterns, common to sociology for instance), and Experimental (discussed here a creating and testing ideas about the world). Each of these ways of working scientifically make use of many of the inquiry skills discussed so far (observing, inferring and communicating, for instance).

Learning the mental disciple of experimental science is of great value to students in schools, and helps them to become critical consumers of scientific claims in the community, and that's an important part of what it means to be scientifically literate (Goodrum, Hackling and Rennie, 2001).

Enriching the Primary Science Curriculum

The beginning of this article included the conundrum of the puff bottle, and Appendix A contains instructions and explanations of how the activity. As we saw, this activity can be used to illustrate all kinds of aspects of working scientifically (such as observing, questioning, explaining, predicting, communicating). Science itself is also much more than the inquiry skills discussed here, but these inquiry skills still play an important roll in the science inquiry classroom today (Carin and Bass, 2001).

Please note that science, and especially school science, does not *have* to progress in the manner described above. What I have presented here is not a teaching approach, as the science inquiry skills are used when they are needed in any teaching approach to make our ideas in science the best they can be. There are also many more activities beside the 'puff bottle' that can help children learn how to work scientifically. Almost any demonstration where children can explore their own explanations of a phenomenon can help learn how to be creators and users of scientific knowledge. Everything from alka seltzer rockets, to flick flaks, to even a balloon inverted into the neck of a soft drink bottle can be used to teach working scientifically skills when student explanations and investigations are explored before teacher driven descriptions.

In conclusion, one of the most important ideas I wish to share is that science is all about creating knowledge, for students and for scientists. When students are encouraged create and test their own ideas, rather than being handed the 'right' answer all the time children will develop greater levels of scientific literacy and enjoy science more (Ireland, 2011). Science is a great opportunity to help students learn how to learn, and to create understandings for themselves based on the processes of science; such as creating and testing theories, observing and explaining observations, and communicating conclusions with their peers.

The intent of this article has been to enrich the options for teaching science in early childhood settings through an examination of ideas on the inquiry skills of science, and to make practical suggestions for including them in school. It has also been to point to other places to look for more information, and to admittedly share a small part of the enthusiasm I feel for science in schools. Science provides daily opportunities to enrich the primary school curriculum. Keep teaching, keep learning, and keep enjoying science!

Dr. Joe is a freelance science educator operating out of Brisbane. He has been teaching for over 15 years in various national and international settings. In 20011 he received his Doctorate in Science Education at QUT, investigating ways in which primary school teachers conceptualise the teaching of science though inquiry.

A special thankyou to all who had a hand in this article, including the editorial team at SER, Felicity McArdle, Claire Christensen and Jim Watters at QUT, and most of all to my eternal wife Samantha Ireland for believing in my dreams.

We welcome responses and feedback to this article. Especially other people's successes, frustrations and stories with the 'puff bottle'. Please visit me at www.DrJoe.com.au

Thankyou for reading my article – Dr Joe.

Appendix: The Science Inquiry Skills section from the natural curriclulum

Science Inquiry Skills

Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting evidence; and communicating findings. This strand is concerned with evaluating claims, investigating ideas, solving problems, drawing valid conclusions and developing evidence based arguments.

Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations. The choice of the approach taken will depend on the context and subject of the investigation.

In science investigations, collection and analysis of data and evidence play a major role. This can involve collecting or extracting information and reorganising data in the form of tables, graphs, flow charts, diagrams, prose, keys, spreadsheets and databases.

The content in the **Science Inquiry Skills** strand is described in two year bands. There are five substrands of **Science Inquiry Skills**. These are:

Questioning and predicting: Identifying and constructing questions, proposing hypotheses and suggesting possible outcomes.

Planning and conducting: Making decisions regarding how to investigate or solve a problem and carrying out an investigation, including the collection of data.

Processing and analysing data and information: Representing data in meaningful and useful ways; identifying trends, patterns and relationships in data, and using this evidence to justify conclusions.

Evaluating: Considering the quality of available evidence and the merit or significance of a claim, proposition or conclusion with reference to that evidence.

Communicating: Conveying information or ideas to others through appropriate representations, text types and modes.

Appendix B: The puff bottle

Introduction:

A child can pretend a balloon is alive, or that they have magic powers over a balloon – allowing others to try and sort out the mystery of how the magic happens. This science activity can be used to illustrate a number of important concepts and processes in science

Focus:

This activity is designed to help students build their own science toy and explore ideas regarding how it (and a great many other things) work.

Suggested National Curriculum Outcomes:

- Planning and Conducting F: Participate in different types of guided investigations to explore and answer questions, such as manipulating materials, testing ideas, and accessing information sources
- Science as a human endeavour 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena.

- Physical sciences 2: A push or a pull affects how an object moves or changes shape.
- Physical sciences 7: Change to an object's motion is caused by unbalanced forces acting on the object
- Chemical science 5: Solids, liquids and gases have different observable properties and behave in different ways
- Chemical sciences 8: The properties of the different states of matter can be explained in terms of the motion and arrangement of particles

Preparation

Always try something yourself before turning up before a class. Also, this lesson plan here assumes you have at least one bottle to demonstrate before the class to get their science thinking happening.

You will need;

- A see through, plastic bottle. Small drink bottles will do, such as sprite or pop-tops. Larger bottles, or bottles of drinking water, tend to collapse under atmospheric pressure. Remove labelling.
- A balloon. Younger children might need to stretch out the balloon before it can be blown up.
- *Adults only*: A means of making a hole in the bottom of the bottle. A drill makes a good hole, but a sharp knife will also do.

Depending on your teaching style, you might like to have children bring bottles to class the week before so you can have the holes drilled prior to the lesson. Alternatively, having the children witness the safe and responsible use of power tools may be just the kind of lesson outcome you're looking for.

Lesson Ideas

Invitation

The teacher claims they are going to try and 'trick' the children with a magic trick, and the children's job is to try and work out how the trick works.

The teacher tells the students the balloon inside the bottle is magical, and they can *prove* it. When they click their fingers it stays blow up even though children can clearly see it is open to the outside air! Then, with a click of their fingers, the balloon obediently deflates on command…

(In reality after the teacher inflates the balloon they plug a small hole at the bottom of the bottle with their finger. Shhh, don't tell them yet!)

Exploration

Point out that scientists try to think of *explanations* of how and why the world works – then they go about testing their ideas. These explanations are often called **Theories** (or more accurately at this stage of the research 'hypothesis') and the tests they use to explore their theories are called **Experiments**.

Have the students propose suggestions regarding why the bottle behaves that way. Test these ideas – could it be the tilt of the bottle? Is it a normal balloon? Will it work without a click? What if someone else holds the bottle?

Remember to praise all attempts at experimentation – experiments always work, even if we don't get the results we expected. This is because the purpose of an experiment is to *learn something new*, not to *prove that we are right*. Therefore, even experiments that don't do what we expected have something to teach us, maybe even more than if they did work out. The goal of science education is to encourage young scientists to be experimenters, not give the impression that only students who get it right make good scientists.

Eventually, students should notice the fingers of the hand holding the bottle moving at certain important times (if not, draw their attention to it with 'maybe the important thing to notice isn't what this clicking hand is doing…?') Allow them to explore the process until they are fully convinced covering the hole, and not a click, makes this trick work.

Concept introduction

Once children have worked out *how* to do the trick, point out that this still doesn't explain *why* the trick works – and these sorts of questions are what it takes to be a scientist.

his trick works because air has a property called air pressure - air is always pushing in all directions – very hard! One way to understand this is because air is made up of tiny nanoscopic molecules that are moving very fast. When they collide with something they give it a little push. Because they are so small their individual pushes are simply impossible to feel, but get a hundred billion of them together and their combined little pushes can inflate balloons, lift up airplanes, and even rip the roof of buildings during a storm.

Sometimes a certain place may have less air pressure that usual – maybe some of the air molecules were taken out, or they are moving slower (because they cooled down) or because they suddenly have more space to move around in (and thus bump into things less often). If one place has less air pressure than the surrounding air, you can be sure that the surrounding air (which is pushing in every direction) will be trying to push into the area of low air pressure. If there is something in between the two places (like the air tight skin of a balloon), it will be pushed by the high pressure air towards the low pressure region.

I like to say that all air, everywhere, is always pushing in all directions all the time. If it's not pushing, it turns into a liquid or solid. This is a great idea for challenging young learners in science – air pressure is invisible, yet so powerful it lifts cars off the road every day (what else is in tyres?) Encourage students who have trouble believing the idea that they can think about it, keep asking questions, don't feel pressured into accepting any idea in science until the evidence and logic convinces you. Who knows, they may yet come up with a better explanation. It matters that they are talking about science ideas they don't fully understand.

Concept Application

How does this relate to our bottle? When you blow into the balloon, you increase its pressure, so it inflates. As it inflates it pushes some of the air out of the bottle. Then you plug the hole – forcing the air in the bottle to maintain its air pressure. The air in the room, however, has the same air pressure it always had, and so continues to push into the bottle the same way it always did. However, instead of finding an equal pressure inside the bottle, your removal of some of the air makes the air pressure in the bottle much lower. So the air in the room pushes the balloon into the region of low pressure, squashing the low pressure air until their pressures again balance out again.

The trick works because air is always pushing – it doesn't need anything other than a high enough temperature to help it. The air in the room is pushing the balloon in because there is less air inside the bottle to stop it.

Try inflating the balloon with the hole blocked right from the start – it's just about impossible. Partly because the hole is small and your finger is pretty strong, but also because even when empty, a bottle is full of air – and air is always pushing.

Extension

How can we increase the air pressure in a certain space? Try putting some hot water in a wrinkled old soft drink bottle and (with the lid on) giving it a shake. This will heat up air inside, giving it more pressure. What will happen to our wrinkled old bottle?

Can the science of air pressure help explain the weather? One reason wind blows is because air will move from regions of high pressure to regions of low pressure, and that's what makes the wind.

Assessment Ideas

Try a poster explaining the science of the puff bottle.

Make up your own puff bottle, try it out on family and friends, then write a report about what they experienced and learnt.

Make a power point presentation of your experiences creating knowledge thought science with the puff bottle. What were your initial feelings? How did you discover how the puff bottle really worked? Do you think scientists use the same kind of process you just did?

Puff Bottles!

Introduction

This fun project helps you build a puff bottle of your own! Trick you family into believing you have *science powers!!*

Safety

Remember to be healthy by **not sharing your balloon** with others – they can use their own balloon or build their own bottle! Also, make sure you **get a grown up to drill the hole** in the bottom of the bottle that you'll need.

Materials:

- Empty soft drink bottles (lids are not required). It is preferable that they are small tops and wide sides, with labels removed. Strong, plastic bottles are best because larger ones tend to crumple.
- A balloon – large enough to cover the opening of the bottle. (Water balloons wont do – unless you have a *very* small bottle!)

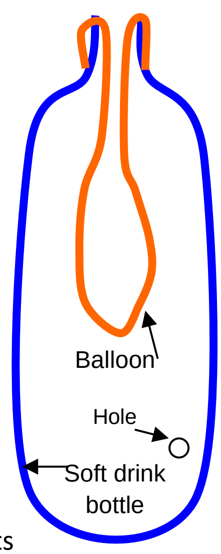
Building the Puff bottles

- Gather the materials and have a competent grown up drill a small hole in the bottom of the bottle – as large as can be yet still small enough to cover with your finger (3-4mm is usually about right).
- It can be helpful if you blow up your balloon once or twice prior to placing them in the bottles as this makes them easier to blow up later on.
- Push the balloon into the bottle and pull the end back over the lid (see the picture). The balloon needs to be open to the outside air (so that it can be inflated) but be sure it seals around the entire top so that no air can escape any other way. Simple as that, you're ready to go!

Using the Puff bottles

A little bit of magical science can go a long way! Blow up the balloon. Then, while you click or clap with one hand you hold the hole closed with your finger – and the balloon stays up! Wait as long as you like and when you're ready, click again and remove your finger – the balloon with 'magically' deflate! Can you friends and family work out how you do it?

Why it works



There are many very good explanations of why this works – here's mine: all air everywhere is pushing all the time – we call it air pressure and it happens because there is a lot of air between you and outer space and it's all pushing down and around you. (And it's not pushing lightly – it's pushing very hard!)

When you blow up the balloon you push the air out of the lower part of the bottle. But then you cover the hole with your finger preventing any air from pushing its way back into the bottle *except* through the balloon which is still open to the outside air – and it pushes the balloon in as far as it can go until it balances the air pressure inside the bottle.

Release the hole, and the air can push into the bottle from both sides of the balloon. As the air pressure evens out the balloon (which was pulled tight like an elastic band) returns to its preferred shape – an uninflated balloon!

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