Enjoying The Science Classroom

Using Interactive Materials To Enhance Understanding

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Abstract

This paper builds on the experience of primary teachers with Questacon, Australia's National Science and Technology Centre, linking primary activities to the science syllabus and building on current educational theories such as constructivism and Multiple Intelligences. This paper not only discusses new ways of presenting science but underlines important fundamental principles of primary science education. The application of constructivist theories in the classroom has increasingly emphasised the importance of relevant contexts in teaching science. Such contexts are not always easy to identify and often the training and experience of primary teachers is not helpful in enabling them to link science to the everyday. This paper, in demonstrating that science can be taught with ordinary familiar things, also makes strong links to experience. Applications of other theories such as ideas of conceptual change are incorporated.

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Introduction – Primary Science And Interactive Science Centres

What can the experience of an interactive science centre offer primary educators? To answer this question, I would like to go back to the genesis of Questacon, Australia's National Science and Technology Centre. It all started in an old primary school building in Canberra, Australia's national capital, where I had been teaching physics for many years at the Australian National University. I had had the opportunity to visit the San Francisco Exploratorium, the earliest truly interactive centre, and was inspired to start something similar on a small scale in my home town. This became Questacon, the first science centre in the southern hemisphere and an institution which was to occupy the next twenty years of my life.

From this part-time and humble beginning, we now have a large and successful centre in Canberra which, like all science centres, engages the public in exciting science which they actually pay to experience! Interactive science centres have proved to be a very popular and powerful way of promoting science to the public all around the world. They differ from other methods of interesting the public in science in that they employ exhibits with which the visitors can experiment. The term 'hands on' is commonly used to describe the interactive devices that are used by visitors. 'Interactive', however, is better because the activity in which the visitors are engaged does not always call for the use of the hands. Frequently one or more of the other senses are brought into use, which I shall explain later in this paper.

People in all walks of life love experimenting; they enjoy trying things out for themselves. From early childhood everyone becomes involved in experimenting with his or her environment. It is a craving that is innate in all of us but is often suppressed. The interactive science centre promotes an atmosphere that is conducive to messing about. It strips away inhibitions and people become enchanted with what they are doing. Teachers have intuitively recognised this from earliest times. Soon after Questacon opened it drew an unexpected reaction from visiting teachers. Chalk and talk had long been the main technique of teaching science, and this led to much disenchantment among students over the years. In the early 1980's, changes began to appear in the Australian school system and there were many teachers who were seeking new and better ways of teaching their students science. The opportunities offered by Questacon were quickly seized. Teachers observed that the interactives were simple and could easily be duplicated and introduced into their curriculum. It was not long before Questacon was running in-service programs to provide teachers with ideas that would readily translate into the classroom. This sort of inservice has also happened in America and Great Britain and indeed right across Asia.

As a follow-on to these in-service programs, I have more recently been involved in outreach with workshops to teachers in Australia and elsewhere. It is the synthesis of this experience which I would like to present here.

The critical issue for successful experiences with science is relevance. If students cannot see where the science fits into their lives, they will quickly rote-learn for the immediate requirements of the school curriculum, then just as quickly, forget! The key to relevance is engagement, preferably hands-on, focused experiences which have been termed "hands-on, minds-on" in science centre circles.

Questacon has a motto:

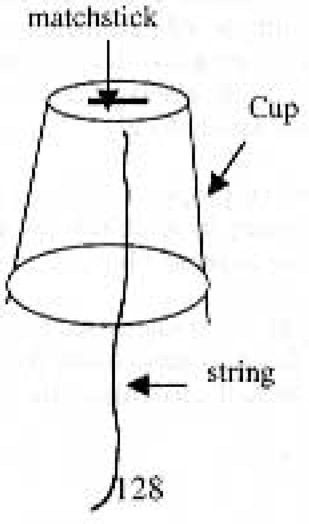
If I hear, I forget
If I see, I remember
If I do, I understand.

This is, of course, the essence of constructivism. The theory of constructivism has stressed that each learner brings their own personal world to the learning experience, interpreting the information according to their own conceptual framework and reworking that framework accordingly. Traditional teaching methods, however, have taken little account of this, instead using didactic, chalk-and talk teaching and textbook based learning. It should not be surprising that students cannot relate to this kind of science.

Theories of learning and the interactive experience

There are many theories of learning which influence students' success in science. I have mentioned constructivism and the importance of relevance and of making connections. Conceptual change theory, which dictates that new information should be intelligible, plausible and fruitful, is very important. If students cannot understand the language of science – if what is said is not intelligible – the lesson will be rejected. If the theory or idea does not make sense to them – it seems implausible – then other previously held concepts will be preferred and retained. The last condition is the most important one of all. If ideas and concepts are not fruitful for the learner, they will be forgotten immediately. Why, indeed, would any sensible person choose to remember something which is essentially useless to them?

In the end, however, the use of simple equipment, elements of humour and of surprise, the telling of stories and a clear scientific "message" are the keys to successful activity in the primary classroom. It is especially successful if your students can go home and show the idea to their family. This may be demonstrated with one simple illustration. The experiment known as the "Clucking cup" is one which can be used to demonstrate highly complex, or very simple, science using the same piece of apparatus. This experiment appears in many primary activity books, often as a "fun" experiment with little explanation. The apparatus you require is a polystyrene cup, a matchstick and a length of string. The string is suspended in the centre of the cup using a matchstick as shown in the diagram.



The string is then tugged using a small damp cloth, and the result is a "clucking" noise. If this experiment is presented in this completed form, students are unlikely to make much connection to the underlying science. It becomes a way of making a noise, but not much else. To make the scientific point, a step needs to be put into the experiment before the cup is constructed. This step is to tug on the string alone. Students will quickly appreciate that the sound produced is almost inaudible. What is required to amplify the sound is, in scientific terms, a "resonance box" – and this is what the cup provides. Parallels may then be drawn with musical instruments – violins and cellos for western students, musical frogs for Thai students, and so on. The level of explanation can be elementary or highly complex, but the apparatus is extremely simple.

A further advantage of simple apparatus like the cup is that it enables the teacher to tap into the various forms of intelligence of the students in the group. The Theory of Multiple Intelligences (Gardner, 1983) underpins the idea that appealing to different senses and skills enhances learning. The theory challenges the traditional view of intelligence as a single capacity that can be measured by IQ tests. Rather, Gardner proposed that there are at least seven (now probably eight or even nine) different aspects of the way in which people prefer to learn. The theory has particular application in science and I would like to enlarge on it here.

The intelligences he described, and the kinds of students who prefer them, are as follows:

1. *Linguistic Intelligence* is the capacity to use words effectively, either orally (e.g., politician, teacher, storyteller, actor) or in writing (e.g.,poet, author, journalist). Students with linguistic intelligence have the ability to manipulate language, its meaning, its sounds and its structure. They are good at oral and written explanations and are skilled in debating. Students who enjoy playing with words, make puns, easily learn other languages, or are good raconteurs, exhibit linguistic intelligence. Science also uses language to explain, to describe and to report. In this way most science teachers exploit linguistic skills of students.

2. *Logical-Mathematical Intelligence* is the capacity to use numbers (e.g., careers such as a mathematician, statistician, or accountant) and to reason logically (e.g., computer programmer). Students with logical-mathematical intelligence have the ability to understand abstract mathematical concepts, to perceive patterns and to understand formulaic relationships. They may also become philosophers! Teachers may detect these skills as obsessions with sporting statistics or as logical, analytical minds. All science teachers exploit these skills in students: it is difficult to take up a scientific career without some measure of logical-mathematical intelligence..

3. *Spatial Intelligence* enables the perception and memory of visual and spatial information. People with these skills may become engineers, guides, architects or artists. If students prefer graphs or pictures to words, or if they 'doodle' all over their notes, they may have highly developed spatial intelligence. They may be highly conscious of colour and form, and are able mentally to manipulate

images in space. Science teachers who use models, pictures, diagrams and graphs are exploiting this intelligence in their students.

4. *Bodily-Kinesthetic Intelligence* uses the ability to employ the whole body in expressing ideas. People with this intelligence are good with their hands – they may become dancers, athletes, artists, mechanics or surgeons. Such people have excellent coordination and often enjoy making things. They are revealed as the ones who would rather make a model than write a report, and who constantly fiddle with paper planes and other creative distractions. Science teachers who encourage constructive projects and who use drama in their classroom are exploiting this intelligence.

5. *Musical Intelligence* favours those who like to interpret the world through sound. Students in this group are sensitive to rhythms and tones. They may become composers or musicians, but they may also simply prefer to learn through repetitive rhythms as an aid to memory.

6. *Interpersonal Intelligence* is the capacity to tap into the feelings of others. Such people respond to facial expressions and voice, and they work effectively with others. They enjoy group work. Students with highly developed interpersonal skills may become teachers, politicians, or salespeople. Science teachers who promote discussion and cooperative group work are exploiting this intelligence.

7. *Intrapersonal Intelligence* describes the ability to understand oneself and one's place in the world. It helps in sensible personal decision-making. Students who know their own strengths and weaknesses, who are self-disciplined and have high self-esteem are exhibiting intrapersonal intelligence. Teachers who promote self-organisation and regulation, who encourage independent learners and foster self-esteem are exploiting and developing this intelligence.

8. *Naturalistic Intelligence* allows people to relate to the environment. They may become farmers or biological scientists, or simply enjoy gardening. They are highly conscious of their surroundings. Science teachers who relate the science to an environmental context are tapping into this intelligence.

Gardner is still gathering evidence for other suggested intelligences, but for now we shall focus on these eight. Let us return now to the simple clucking cup activity. First, it involves following instructions in a logical order, and understanding the theoretical differences between the simple string and the string-plus-cup activity. These utilise the first two intelligences. Next, it uses model making, hands on activity and the ability to make music. Next, it is carried out in a group, with all of the attendant enjoyment of large numbers of people making an unspeakable noise. In effect, this very simple activity uses almost all of the intelligences described by Gardner. How much more enjoyable, more satisfying and more creative is this than reading about resonance in a text book!

The simple science theme and the problems of textbooks

Teaching science *should* be enjoyable for primary teachers, not a threat. The key to this is that it should be regarded as a shared journey with the students, rather than having the teacher becoming stressed, as so many tell us they do, because they "don't know all the answers". I tell primary teachers that there are hundreds of highly paid scientists in our country that do not know the answers – they call them researchers! Primary textbooks are often not helpful in this regard. Many contain incorrect science, carried over from previous generations of textbooks. One such example is the candle in a glass jar, burning over water that rises up the jar when the candle goes out. This is often explained, incorrectly, as being due to the oxygen being used up. In fact it is a simple pressure-temperature-volume change, but there are still many primary texts which perpetuate this error. Other texts carry complex explanations, or inadequate explanations, leaving teachers feeling inadequate too. The most common feeling I encounter from primary teachers is uncertainty and fear of teaching science.

In Australia, two states in particular have focused on primary science and produced some excellent materials. Even these, however, expose the primary syllabus as overcrowded and full of unrealistic expectations of teachers. One such program is a whole-school course, which incorporates many hands-on activities graded to match the age of the students. Major themes are suggested for each age-group, such as "Science is patterns" for very young students, or "Science is energy" for older ones. The trouble with this program, innovative as it is, is that the themes it develops are not intuitively obvious to students or to teachers. The activities are, therefore, haphazard and unrelated in the minds of many teachers and often totally unrelated in the minds of students. This problem underlines the fact that science is a constructed discipline, whose relevance needs to be understood by students and teachers alike. If it is not relevant, and not easily transferable to the world outside the classroom, we should not be teaching it at primary level. Our students should always be able to go home and explain what they learned and why.

Teachers of primary science need to be confident of what they teach, and to understand it. This means being honest with them, not giving a superficial and unsatisfactory explanation for phenomena they are required to teach but not, on the other hand, providing a textbook style explanation which is too difficult for their likely science background. We have, in my view, developed primary science to the point where it is often very unfair and unrealistic for primary teachers. The solution is not just to teach them more science when undergoing teacher training, but to accept that students and teachers alike at this level need to keep it simple, to explore and to create. One way to be creative and exciting is through science theatre.

Science as theatre

Whatever science centre you visit, anywhere in the world, you will find that it presents science demonstration shows, usually about twenty minutes long and covering a multitude of subjects. Their origins go back a long way–probably back to the beginnings of the Royal Institution at the turn of the eighteenth century. The Royal Institution, under the leadership of people like Benjamin Thompson, (Count Rumford), Humphry Davy and Michael Faraday introduced a policy of offering popular lectures to the public.

Faraday's lectures are legendary. He believed in making science accessible and entertaining for the lay public. He maintained that, in order to hold an audience's attention, it was necessary to 'strew the lecture path with roses'. It is a philosophy that is not espoused by very many scientists even today, but out of these lectures developed the famous Christmas Lectures that are broadcast to millions of television viewers all around the world.

Science demonstrations in the classroom should strive for similar engagement. The all-too familiar picture of demonstrations using unfamiliar, alien apparatus to show an obscure scientific principle is one which should never be seen in any classroom, let alone a primary one. At Questacon, the science show using simple, homely apparatus has blossomed into a full-scale travelling program – the Shell Questacon Science Circus, which visits rural Australia with shows and exhibits for schools and the general public. The essence of these shows is simplicity, but the science is absolutely sound. The presenters are excellent young scientists who are role models and who graduate at the end of a year with a Graduate Diploma in Science Communication from the Australian National University. I stress the simplicity of their demonstrations because we have found over the years that they have immense appeal for teachers. Indeed, it is not uncommon for young students to tell us that they have seen a demonstration before – and we realise that their teacher, having seen it previously, has incorporated it into their program. Good, simple demonstrations are appealing and infectious!

There are many different forms of science shows and demonstrations with applications to the primary classroom. These include the one-off, quick demonstration to make a particular point or a series of demonstrations around a theme. For example, the clucking cup might be accompanied by the musical straw to demonstrate sound in open pipes, and by drums to demonstrate vibrations of a diaphragm. These thematic shows are the most common type in science centres. Usually there is a loose but coherent story line and the emphasis is on real world relevance.

In recent years a number of longer presentations have been produced, centred on particular scientific personalities. Typical of these are Questacon's presentations on Archimedes, Galileo, and Alan Turing. They address the science but they place it in the context of history, with biographical details of the person concerned. There is rich scope here for primary science, using the various skills of young writers, actors and budding scientists to explain some concepts in drama and mime. Scientific history can be brought to life in a rich and entertaining way. An outstanding example of such theatre has been a very successful series of short plays delivered to children in London's *Molecule Theatre*. Each play revolved around a particular scientific topic coupled with a scenario aimed to capture the children's attention and imagination. One example, concerned with various aspects of mechanics like levers and friction, was about a robbery during which two thieves attempted to steal a heavy safe. They enlisted the help of the audience in much the same way as in English pantomime. The actors explained what they intended to do and how they intended to do it, and then asked the audience to comment *en masse* for their opinion. Last, the medium of puppetry is particularly successful with younger audiences. The technique has been used in many different parts of the world.

Where do I get the apparatus?

One of the problems facing teachers is the issue of scientific apparatus with which to provide hands-on activities. Most textbooks, even primary activity books, intimidate primary teachers with complex equipment which takes time and much effort to set up. Primary teachers quite simply do not have the time. Once again, the science centre experience has something to offer which frees up teachers to choose a simpler path.

Here are some rules for science equipment for primary schools, derived from exhibit design.

1. *Keep it simple..* Don't try to make apparatus complicated. If it is too complicated it may well not achieve its aim. Rather than making the concepts clearer, they become confused in the mind of the observer. Furthermore, the more complicated the apparatus the more difficult it is to keep it working. Things which don't work discourage students. How often have you heard people demonstrating science experiments preface their demonstration with "I hope this works!" This should never be an issue. Simplicity reduces the amount of maintenance required and the amount of skill to operate the equipment.

2. *Avoid labour intensive apparatus.* These are the experiments that require you to replenish materials regularly. This is one of the main problems with chemical experiments in which reagents need to be regularly replaced. If an experiment is in the cupboard more than it is in the classroom, scrap it! One problem may be that it takes too much time to set up, or to clean up. Questacon once had an exhibit that used dried peas to enable visitors to discover something about large numbers. Within 30 minutes of it being placed in the display gallery it was scrapped–never to return. The younger visitors preferred to throw the peas all over the floor rather than use them for the purpose for which they were intended. The designer believed it was a great exhibit but had not allowed for human nature.

3. *Make it attractive.* There is a large body of opinion that believes that interactive exhibitions should be colourful as it makes them far more enticing. This applies no less to classroom experiments. Cheerful, friendly apparatus is enticing. Black boxes – meters, wires, intimidating equipment – are alienating.

4. *Do not use too many words in the instructions.* Only a very few students will spend time reading long winded instructions and explanations. In particular, there is much evidence to show that boys will rush in without too much reading and get started, often with poor results. Structure the activity so that that cannot happen.

5. *Adopt the broomstick philosophy.* If you can construct an activity out of something like a broomstick, then if it is lost or if it breaks it is easy and cheap to replace. More to the point, it is not necessary to have a skilled technician to carry out the replacement. Of course, this is a difficult goal to achieve, but it does provide a benchmark for success in classroom science. Furthermore, it will be a familiar object to all your students. They will feel comfortable and at home with it.

Yes, but what do they learn?

A question I often hear is, 'Yes, interactive science centres are all very exciting but what do people actually learn in a science centre?' This may be extended to the often heard refrain about school science – it isn't supposed to be fun! Let me state here that it is wrong to infer that interactive science centres are engaged in teaching scientific facts to their visitors. They are not, and were never intended to be all about learning new facts. In this connection, primary classrooms should not be about learning facts either.

Frank Oppenheimer, once said, 'Nobody flunks a science centre!' Science centres are designed to excite, to engage, to inspire. Not to encourage failure. What excellent models for formal education!

I believe that there is absolutely nothing like exploring - messing about with science and I know a lot of scientists who agree with me. Until recently, however, very little research into what people take away from science centres had been carried out. Now we know that people are indeed changed by their visits and that informal learning does, in fact, take place. The lessons are there for formal educators, if they choose to heed them.

I am convinced that interactive science centres must be both relevant and entertaining. Unhappily there are those who believe that, by making the science entertaining, it is somehow devalued. It is a strange view: no one would object to the notion of being entertained by an opera, a play or a concert, but science is somehow seen by many as different from other aspects of our culture. The last word in this matter should go to a science Noble Laureate. Konrad Bloch, the biochemist, said in his acceptance speech that 'science is the ultimate in entertainment'.

So, finally, what is my message for primary teachers? It is to strive for engagement, for positive attitudes, for interest and for relevance. The more variety you can introduce, the more successful you will be. At our Centre, we always say that there are three rules for successful communication of science. The first is "Keep it simple'. The second is "Keep it simple" And the third is "Keep it simple"!

Reference

Gardner, H. (1983). *Frames of Mind: The theory of multiple intelligences.* New York: Basic Books.

Title : **Enjoying the Science Classroom – Using Interactive Materials to Enhance Understanding**

Presenter : Prof. Dr. Michael M. Gore
Australian National University

Date & Time : 12 August 2003 (Tuesday), 2.00 pm – 3.00 pm

1. Content of the paper

1.1 This paper discusses new ways of presenting science, building on current educational theories such as constructivism and Multiple Intelligence.

1.2 The application of constructivist theories in the classroom has increasingly emphasized the importance of relevant contexts in teaching science.

1.3 The presenter demonstrated how science can be taught with ordinary familiar things, and makes strong links to experience.

2. Discussion

2.1 *Madam Salbiah Md. Som from Curriculum Development Center, Ministry of Education Malaysia* commented that science teachers are usually not creative in teaching science and raised a question on how can science teachers be more creative.

Answer
Creative teaching is through practice and experience. Brainstorming sessions can be used to find ways on how to teach science differently and interestingly.

2.2 *Madam Harison Yusoff from Petrosains* enquired whether there has been any quantitative research done to establish a connection between science centres with the performance of science education.

Answer
For further details of such studies, the speaker asked Mdm Harison to refer to Dr Stocklmayer.