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When learning science becomes child's play p. 2

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Roadblocks can be lifted

If we miss the boat for achieving environmental sustainability by 2015, we can wave good-bye not only to this Millennium Goal but also to many others, warns a major study published on 30 March. 'Any progress achieved in addressing the goals of extreme poverty and hunger eradication, improved health and environmental protection is unlikely to be sustained if most of the ecosystem services on which humanity relies continue to be degraded', says the study, which describes the ongoing degradation of ecosystem services serves as a 'roadblock' to achieving the Millennium Development Goals agreed upon by world leaders at the United Nations in 2000. According to the study, 60% of the ecosystem services supporting life on Earth are being degraded or used unsustainably.

The fruit of a four-year global assessment by a team of UN agencies – including UNESCO – international scientific bodies and development agencies, the *Millennium Ecosystem Assessment Synthesis Report* claims there is now enough evidence for experts to warn that the ongoing degradation of 15 of the 24 ecosystem services examined – including freshwater, capture fisheries, air and water regulation, and the regulation of regional climate, natural hazards and pests – increases the likelihood of potentially abrupt changes that will seriously affect human well-being. This includes the emergence of new diseases, sudden changes in water quality, creation of 'dead zones' along the coasts, the collapse of fisheries and shifts in regional climate.

The study confirms what many have long suspected: that it is the world's poorest who bear the brunt of ecosystem changes. The regions facing significant problems of ecosystem degradation – sub-Saharan Africa, Central Asia, some regions of Latin America and parts of south and Southeast Asia – are also those finding it hardest to reach the Millennium Goals. In sub-Saharan Africa, for example, the number of poor is forecast to rise from 315 million in 1999 to 404 million by 2015. Southern Africa is unlikely to be spared, as we shall see from one of the sub-regional reports for the Millennium Assessment, reproduced in this issue.

As this issue goes to press, the G8 countries have just agreed to write off the debt of 18 of the world's poorest countries: Benin, Bolivia, Burkina Faso, Ethiopia, Ghana, Guyana, Honduras, Madagascar, Mali, Mauritania, Mozambique, Nicaragua, Niger, Rwanda, Senegal, Tanzania, Uganda and Zambia. A further nine may soon join them. Freed from the stranglehold of debt, this first group of countries will now dispose of $1.5 billion in annual savings from debt repayments to invest in such areas as education, health and the environment. It could make all the difference to their chances of meeting the Millennium Goals.

W. Erdelen
Assistant Director-General for Natural Sciences

When learning science becomes **child's play**

© David Jasmin/*La main à la pâte*

What happens to food after we swallow it? A class in Nankin, China. The La Main à la pâte programme here is run by the Chinese Ministry of Education and the University of Nankin

The recent development of inquiry-based science teaching in primary schools owes much to the efforts of the scientific community. It was Leon Lederman, Nobel Laureate for Physics 1988, for instance, who introduced the movement into poor neighbourhood schools of Chicago in the USA. Three French physicists would later visit these schools, only to discover children fired with enthusiasm for science. Upon their return to France, the three physicists – Georges Charpak, Nobel Laureate for Physics in 1992, Pierre Léna and Yves Quéré – would decide to launch their own version of inquiry-based science teaching, *La main à la pâte* (or Learning by doing).

Over the past five years, the movement has spread to schools in Afghanistan, Argentina, Brazil, Cambodia, Chile, China, Colombia, Egypt, Malaysia, Mexico, Morocco, Senegal, Slovakia, Togo and elsewhere. Together with David Jasmin, responsible for the programme's international activities, Yves Quéré explains here how *La main à la pâte* has caught on around the world.

It all began in France in 1996 when we learned from the Ministry of Education that science was being taught in just 3% of classes in kindergartens and primary schools. This startling figure reflects, above all, just how much teachers dread having to teach a subject they believe has become too difficult. Science has undoubtedly made dizzying progress but what teachers don't seem to realize is that the basic concepts they should be showing children have not changed.

Having visited schools in the suburbs of Chicago, we suggested to the Minister a modest experiment which had the unanimous backing of the French Academy of Sciences. The experiment would involve 350 teachers keen on revitalizing science teaching for children, who would teach the inquiry-based method developed by *La main à la pâte* (see box). There was nothing really new about this 'teaching recipe', except for a few novel ingredients. A set of ten principles summing up the general idea behind *La main à la pâte* was drafted and presented to the teachers.

There are two extremes in teaching, if we set aside the 'hybrid' methods inbetween. One is the top-down, or vertical, method: the teacher deposits knowledge, by gravity as it were, into the brain of the pupil, who is then required to store and hopefully retain this knowledge. Through this tried and true method, the child memorizes a remarkable store of knowledge. Its weak point is that this method of rote learning often attaches little importance to whether the child actually understands the concepts and ideas she or he is learning by heart.

Keeping to our geometric metaphor, we shall call the other extreme the horizontal method. Here, the teacher takes the pupil by the hand and leads him or her on a voyage of discovery, stimulating the child's observation skills,

© Élèves de lécole de l'APET à Kpalimé

For the launch of La Main à la Pâte *in Togo, the theme of water is chosen. In this school at Kpalimé, the programme for classes at all levels involves school outings, using a scientific album and talks by water specialists. (Left) A visit to a vegetable garden. (Centre) Upon their return, the children study the water needs of a plant. (Right) After reading an album, pupils from the Kpodzi Kindergarten in Kpalimé are conducting experiments on the theme of 'Does it sink or float?' This programme is being run in parallel with a multidisciplinary project called @llo ! A l'eau involving Ms Liska-Baptiste's class of 8–9-year olds in France* imagination, curiosity and reasoning capacity. Given the time it takes pupils to make discoveries of their own, to reflect on what they see and express themselves orally or in writing, the amount of knowledge acquired is obviously less than with the top-down method. However, the horizontal method gives children a desire to understand and a mental elasticity which will help them to adapt better to our highly mobile social and professional world.

There is nothing new in this. It would not be farfetched for a Frenchman to imagine his Magdalenian[1] forebears using both of these methods: teaching his child of an evening, in the cave they call home, the names of fish or the best shape for hooks, before taking him next morning to the river for a practical fishing lesson. More recently in France, the laureate of the Nobel Prize for Physics (1903) and Chemistry (1911), Marie Sklodowska Curie, dextrously juggled the top-down approach with her students at the *Université de la Sorbonne* and the horizontal method with 7–8-year old children, whom she helped to discover physics by making them do it themselves using their own hands and brains.

1. *The Magdalenian period (between 17 000 and 10 000 years ago) represented the height of prehistoric cave art in France*

© Pamela Lucas/*La main à la pâte*

In this Colombian primary school in Bogotá, the 11-year old pupils are still at the stage of making forecasts. They are discussing ideas before beginning a series of experiments on mixtures. In the insert are the jars containing the different mixtures the children will later create. Pequeños Científicos programme (University of Las Andes/French Lycée of Bogotá/ Maloka Centre)

We knew that both of these approaches had their place but also that each was appropriate at a particular stage of the curriculum. For our purposes, we opted for the second approach, knowing full well that, as pupils progressed beyond the primary level, the top-down approach would have to be used more and more.

The ten principles of *La main à la pâte*

The teaching approach

1. Children observe an object or a phenomenon in the real, perceptible world around them and experiment with it.
2. During their investigations, pupils argue and reason, pooling and discussing their ideas and results, and building on their knowledge, since manual activity alone is insufficient.
3. The activities suggested by the teacher are organized in sequence for learning in stages. The activities are covered by the programme and leave much to pupil self-reliance.
4. A minimum schedule of two hours per week is devoted to the same theme for several weeks. Continuity of activities and teaching methods is ensured throughout the entire period of schooling.
5. Each child keeps an experiment logbook, in which the children make notes in their own words.
6. The prime objective is the gradual acquisition by pupils of scientific concepts and operating techniques, with consolidation through written and oral expression.

Partnership

7. The family and community are solicited for work done in class.
8. At the local level, scientific partners (universities, etc.) support classwork by making their skills and knowledge available.
9. Teaching colleges in the vicinity give teachers the benefit of their experience.
10. Teachers are able to obtain teaching modules, ideas for activities and replies to queries via the Internet. They can also take part in a dialogue with colleagues, training officers and scientists.

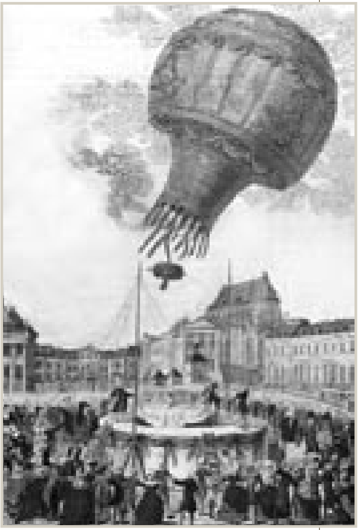
For more details: www.inrp.fr/lamap

© Laura Pacheco

(Top) These kindergarten pupils at the French Lycée in Buenos Aires, Argentina, are trying to light a bulb using a battery. This experiment favours a personal discovery of the concept of a closed circuit. (Lower photo) A lesson on recycling paper at the same school

Lighter than air

Joseph (1740–1810) and Etienne (1745–1799) Montgolfier were respectively the twelfth and fifteenth of the sixteen children of Pierre Montgolfier, a paper manufacturer in Vidalon-les-Annonay in France.



In November 1782, Joseph travelled to the town of Avignon to sell paper to the printers in the region. In his room, a fire in the grate heated his shirt. As Joseph was mulling over the siege of Gibraltar by the French navy (Gibraltar is a rocky outcrop of 5 km^2 at the mouth of the Mediterranean, belonging to the United Kingdom), he approached the mantelpiece and saw his shirt billow. His mind made a correlation between the two observations: surely it would be easier to enter Gibraltar using airborne craft inflated with hot air than by sea. Joseph cut out and sewed a square of cloth, which he then held over the fire. When he let it go, the cloth began to rise. This idea might work, he realized.

Back home in Annonay, Joseph pursued his experiments with Etienne. The brothers had already thought of blocking hydrogen in little silk or paper envelopes but had been unable to prevent the gas from escaping. They succeeded, however, in getting little round balls filled with hot air to rise.

On 4 June 1783, Joseph and Etienne Montgolfier demonstrated their balloon for the first time to an admiring crowd in Annonay (see sketch). The balloon rose to almost 1000 m and covered a distance of 2 km in 10 minutes. At the behest of the king, they repeated the exploit at the Palace of Versailles five months later. The passengers on this second flight were a rooster, a duck and a sheep. Not until its third flight, on 21 November 1783, did the hot-air balloon transport human passengers.

It is not hard to imagine how this exercise develops a child's imagination and observation skills. The child rubs shoulders with the concept of truth, learns to question preconceived ideas expressed by others or rooted in the child's own prejudices. He or she acquires a new awareness of the universality of laws, the absurdity of racism, and the global nature of the world we live in. His or her mastery of language improves – science has no time for imprecise words or unfounded assertions. The child discovers the virtues of teamwork and acquires the manual skills needed to prepare and carry out an experiment.

By way of example, we could cite the class curious to understand what was meant by 'rhythm'. The children made rudimentary pendulums out of weights attached to a piece of string. Swinging the pendulums back and forth, they then measured the periodic regularity of the motion (or the oscillation) and tried to work out why the pendulums moved at different speeds. Each child was convinced – and could not hide a certain complacency – that their idea was the 'right' one. It took some time and a lot of patient reflection on the separation of the different parameters before the truth was revealed: the time it took for the pendulum to swing back and forth in a full cycle did not depend on the weight, nor on the thickness of the string, nor on the initial impetus nor on how the knot was tied (all hypotheses suggested by the children) but solely on the length of the pendulum. This was a superb lesson in that it taught the children much more than a simple physics formula: the teacher's clever commentary helped the children to realize that any real phenomenon – not only physical but also climatic, sociological or epidemic – cannot be interpreted, let alone understood, until all

The teaching technique

Teachers usually set the ball rolling by quizzing the children about inert objects (such as rocks, water and the sky), living beings (insects, the human body, plants and so on) and natural phenomena (winds, tides and climate). Rather than giving an answer, the teacher turns the question back to the children. 'What do you think?', thus inviting them to advance their own hypotheses. Even the most naïve of these hypotheses is accepted on face value. The next step is to stage an experiment. This usually involves four or five children working in a small group. The children decide which is the best hypothesis and, ideally, answer the question. To round off the lesson, the children are encouraged to express themselves by noting the practical and intellectual adventure they have just experienced in their 'experiment logbook'.

Archimedes' Law of Buoyancy

As legend has it, the law of buoyancy came to Archimedes (Sicily, ca 287–212 BC) while he was taking a bath. On seeing the bathwater overflow, he realized that the density of an object (in this case his own body) could be measured by determining how much water the object displaced. Archimedes was reportedly so excited by his discovery that he ran naked through the streets shouting 'Eureka!' 'Eureka!' ('I have found it!' 'I have found it!').

The action exerted by water on an object plunged into its midst is today known as Archimedes' Law of Buoyancy. According to this principle, when an object placed in water is weighed and its weight in the water is compared to its weight out of the water, the object loses an amount of weight that is equal to the weight of the water it displaces. It is easier to carry an object in water than out of it, as anyone who has ever carried a person in a lake, or dragged a net full of fish out of the water, will know.

The principle of Archimedes holds not only for water but also for gases like air. Gases are not very dense, so the force they exert is weak; they are sufficiently dense however for a balloon of 1400 m^3 at Versailles to carry three passengers on 19 September 1783: a rooster, a sheep and a duck (see above *Lighter than air*).

Galileo's telescope

Galileo Galilei (1564–1642) was teaching astronomy at the University of Padua (Italy) when he learnt in 1609 of the invention of the telescope in Holland (The Netherlands). Relying on the barest of descriptions, Galileo built himself a model far superior to the original. With this, he was able to study the heavens and position the four satellites of Jupiter, which he named Medicean stars in tribute to his benefactor, Lorenzo di Medici.

Galileo reported his discoveries in *Sidereus Nuncius* (*Starry Messenger*, 1610). On the Medicean stars, he wrote, 'Here, we have a fine and elegant argument for quieting the doubts of those who, while accepting with tranquil mind the revolutions of the planets about the sun in the Copernican* system, are mightily disturbed to have the moon alone revolve about the Earth and accompany it in an annual rotation about the sun. Some have believed that this structure of the universe should be rejected as impossible. But now we have not just one planet rotating about another while both run through a greater orbit around the sun; our own eyes show us four stars which wander around Jupiter as does the moon around the Earth, while all together trace out a grand revolution about the sun in the space of twelve years'. (Translation made available by Bard College, USA)

From his observations of celestial bodies rotating around a body other than the Earth, Galileo constructed his heliocentric theory placing the sun at the centre of our solar system. In so doing, he refuted Ptolemy's theory (Egypt, ca. 90–168), according to which the bodies of the solar system circled the Earth (geocentric theory).

* *Galileo was able to confirm the truth of the sun-centred theory expounded by Polish physicist Nicolaus Copernicus (1473–1543), according to which it was the planets that revolved around the sun and not the reverse.*

the different elements have been separated and documented. The children learnt that neglecting that rule opens the door to falsifications and to all the political and sectarian manipulations to which children might be exposed.

Some new ingredients

Neither our ancestors nor Marie Sklodowska Curie ever knew the Internet, of course. This modern tool has proved extremely effective in expanding the outreach of *La main à la pâte*. It is very popular with teachers, 200 000 of whom visited our site every month in 2004. Our website has three missions: to makes resources available to primary school teachers in the form of multiple experimental sheets, scientific data and teaching tips; to provide a vast "chat forum" enabling teachers to talk to each other, compare teaching methods, share their successes, describe problems and propose sequences they have devised themselves to colleagues. It is remarkable that the forum has quite naturally opened up to subjects other than science, such as grammar and history; and lastly, to create a whole new relationship between the world of teachers and that of researchers. Some 100 high-level scientists have agreed to answer questions on elementary science gratuitously within 48 hours. The questions and answers are naturally made public and by the end of 2004 represented a repertoire of over 1000 entries.

The website has engendered others. A dozen regional sites have been set up in France proposing activities adapted to local circumstances and resources. All the sites are networked with a shared search engine and common charter. Since 2000, this strategy has been extended beyond France: activity sheets have been translated and posted online at partner sites: a mirror site in China[2], sites in Brazil and so on. By the end of 2005, sites will be online in Portuguese and Spanish (Universidad de las Andes), Serbian (Vinça Institute of Nuclear Sciences, Serbian Physical Society) and Arabic (Bibliotheca Alexandrina).

Furthermore, a quadrilingual site[3] enabling copyright-free resources to be shared among ten countries engaged in reforming science education has been created. To complement this, *La main à la pâte* has opened a bilingual portal on science teaching in primary schools to showcase the teaching activities of members of the International Council for Science (ICSU) and InterAcademy Panel (IAP)[4]. It also features a brief description of science education systems in different countries, the proceedings of symposia on science teaching in primary and secondary schools, and synopses of publications on the subject.

2. *University of Nanjing: www.lamap.handsbrain.com*
3. *This experimental site covers: Belgium, Brazil, Canada, (Québec), Chile, Colombia, Egypt, France, Morocco, Serbia & Montenegro and Spain: www.mapmonde.org.*
4. *Yves Quéré is co-president of the IAP, an international network of academies of science*

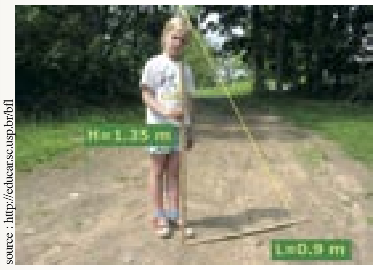
This class of sixth-year primary pupils from Phnom Penh, Cambodia, is working on levers, a project adapted from an activity developed in France. The children have been asked to devise a system for lifting a 50 kg bag of rice. In collaboration with the programme of the Agence universitaire de la francophonie and the Cambodian Ministry of Education

Measuring the Earth is child's play!

Since September 2000, 8–14-year olds have been measuring the circumference of the Earth using a method devised by Eratosthenes, Director of the Bibliotheca Alexandrina, 22 centuries ago. The children place a stick vertically to the sun and measure the length of the shadow when the sun is at its peak. They then deduce the angle of the sun's rays in relation to the vertical line of the stick. The children exchange their results with another class living at a different latitude. A few geometric strokes and a rule of three (the method of finding the 4th term of a proportion when the other three are given) enable the children to evaluate the length of the Earth's meridian (a circle of constant longitude passing through a given spot on the Earth's surface) at their latitude.

As of 2005, some 52 classes, mainly from France but also from Belgium, Brazil*, Cameroon, Canada, Egypt, Latvia, Malta, Poland, Serbia & Montenegro and the United Kingdom were participating in the project.

More measurements are needed to complete the experiment. Your class can join in by going to: www.inrp.fr/lamap/eratos. The French Ministry of Education has created pages in English: www.educnet.education.fr/phy/interpc/eratosa.htm



source : http://educar.sc.usp.br/bfl

(Left) In front of the Bibliotheca Alexandrina, this Egyptian class is measuring the Earth's circumference on the day of the summer solstice, 21 June, at the very place where Eratosthenes took his measurements all those years ago. (Right) On the same day, this Latvian girl is measuring the Earth's circumference in Dzerbene. The vertical angle from the sun measures 33°10"

*Visit the Brazilian site: http://educar.sc.usp.br/bfl/

A science coach for teachers

A scientific coaching programme for teachers has been launched in France. This brings teachers into direct contact with scientists to complement the initial and on-going training provided by teacher training colleges. The coaching programme instigates a more personal relationship with the scientists and engineers who agree to go into schools (not to teach but to help teachers introduce the inquiry-based method), or with the students who fulfil the same role, more and more often as part of their university course.

The scientific coaching programme has been so successful that a *Coaching Charter* was even drafted in 2004 and endorsed by the French Ministry of Education. The *Charter* outlines both the best practices and those to avoid. It underscores, for instance, that the scientist is in the classroom to assist the teacher and not to teach the class.

It works both ways

We have evoked experiments launched in the USA and actively encouraged by the US National Academy of Sciences but science education for children has been thoroughly overhauled in many countries in recent years. By way of example, we could cite the remarkable initiatives by Wei Yu in China, Maurizio Duke in Colombia and Jorge Allende in Chile, not to mention the growing number of international conferences on the subject.

Many countries have made bilateral contacts and signed agreements, often between science academies, leading to active co-operation. This is particularly the case for Afghanistan, Argentina, Brazil, Cambodia, Chile, China, Colombia, Egypt, Malaysia, Mexico, Morocco, Senegal, Slovakia, Switzerland and the USA. Courses for teachers and trainers have been organized with two-way translation of documents and exchanges of teaching material. The virtue of these exchanges is that they are of mutual benefit. For instance, some of our books and documents have been translated into Chinese; in exchange, Chinese texts for kindergarten teaching have been translated into French.

Moreover, a number of scientific activities have been launched which simultaneously bring into play schools from different countries. European Discoveries, for example, introduces European children to discoveries from their continent. These discoveries are placed in their historical context. There is the hot-air balloon invented by the Montgolfier brothers in 1783 (a beautiful illustration of Archimedes' Law

© Elisabeth Plé, IUFM de Reims

These girls at Dourani High School in Kabul are about to discover the temperature at which water boils. Although they are fifth-year pupils (high schools in Afghanistan cover all levels of schooling), the girls are aged about 14 (Ed. owing to the three years of schooling they lost under the Taliban, who banned schooling for girls until the fall of the regime in 2002)

© Edith Saltiel, *La main à la pâte*

This class of 8-year olds in Cairo, Egypt, is working on the five senses. The pupils have been asked to identify the object inside the mysterious container without opening it. The children are being encouraged to compare, describe and draw parallels between the sounds coming from the different objects in the container

© José Braz Mana

The challenge of the straw tower. At the same time on the same day, 20 pupils from each of the participating countries (Brazil, Canada, Colombia, Egypt, France, Morocco) – here one of the Brazilian teams – had to build the highest tower possible using 100 straws and 100 paper clips. Once the tower was completed, they had to test its strength by attaching weights of 10 g to the summit. Their efforts were transmitted live via Internet (www.mapmonde.org). The concepts targeted were: how the materials used and the shape of the tower related to the strength and resilience of the structure

of Buoyancy), the Galilean telescope or Volta's battery… (see boxes) and so on. All are perfectly suited to scientific experimentation in the classroom.

Likewise, since 2000, children aged 8–14 years have been measuring the circumference of the Earth using a method developed 22 centuries ago by Eratosthenes, Director of the Bibliotheca Alexandrina. Participating classes from more than a dozen countries are contributing to the project by exchanging and comparing their measurements taken at different latitudes (see box on p. 6).

Children take up the challenge

The international science challenges were inaugurated by *La main à la pâte* in June 2004 and so far involve ten classes in different countries. Thanks to new computer platforms making it possible to view videos transmitted from different locations in real time and in parallel via Internet, each of the competing classes can be filmed simultaneously by a webcam(era) as it tackles a given scientific or technical challenge, the same for every class.

One of these science challenges saw 8–11-year olds build a vehicle capable of protecting an egg dropped from a height of 2 m. The 'egg-tronaut' had to survive the landing without cracking its shell.

Another challenge involved classes from six countries. Each group of 9–10-year olds was asked to build a structure using 100 straws and paper clips, in an exercise from the construction module. The jury presided by Georges Charpak awarded prizes in four categories: for the highest tower, the most original tower, the most beautiful tower and the strongest tower (see above one of the Brazilian teams in action).

Making education child's play

The current disaffection for scientific disciplines at university, coupled with the need to open the minds of children to observation, deductive reasoning, teamwork, free thinking and universal truths (which do not conflict with local cultures), leaves us no choice but to rethink the way we teach science to children, if we want them to enjoy learning and to think both imaginatively and rationally.

© Défi

In small groups, these children at a school in Port-au-Prince, Haiti, are dissecting a rabbit and observing its different organs. They are in the process of inflating the rabbit's lungs using a straw introduced into the animal's throat. Programme implemented by the NGO Défi, with support from the Mérieux Foundation

© Maria da Luz

Within the European Discoveries project, children from Figueira da Foz in Portugal are putting together a herbarium of medicinal plants. They are reproducing the work of Garcia de Orta (ca. 1499–1568). This Portuguese naturalist and doctor taught his students the importance of observation and of using the senses to study the natural world. In collaboration with Ciência Viva, an agency of the Portuguese Ministry of Science and Technology