Telepresentation by Roy McWeeny

from his home in Pisa, Italy

during the Second Advanced International Colloquium on
Building the Scientific Mind

held in Vancouver, BC, Canada, 28-31 May 2007

Program item:

For the Love of Science: Reaching out to the as yet unreached

Wednesday, 30 May 2007 - 09:00-09:30 a.m.

I'm speaking from my home in the heart of old Pisa, two or three hundred metres from the house where Galileo was born in 1564 and a few minutes walk from the famous tower where he reputedly performed his experiments on falling bodies. Galileo has long been considered the originator of true scientific method: observe, speculate and make hypotheses, use argument - often in mathematical form - to make predictions; and return to observation to test your conclusions.

Not far away, near the small town of Vinci, Leonardo was born 100 years earlier. These two great Renaissance figures struggled throughout their lives to defend their originality and creativity in the face of superstition, religious dogma, and blind acceptance of what Aristotle had said, many centuries before them.

Some attributes of the Scientific Mind

INSATIABLE CURIOSITY – must surely be the mainspring

The need to **OBSERVE** – with objectivity and impartiality

The need to **QUESTION** – seeking answers (through the framing of hypotheses)

The **CREATIVE URGE** – a desire to create new things (with the hands or in the mind)

A talent for **IMMAGINING** possible actions and their consequences – i.e. for abstraction

A capacity for **LOGICAL ARGUMENT** – to connect ideas

The power of **DISCRIMINATION** – what is important to an argument and what is not?

An appreciation of **BEAUTY –** both visual and intellectual

A SENSE OF WONDER – at the immensity of the Universe and the diversity of Nature, both living and non-living.

Slide 1

Whereas Galileo developed the sciences of mechanics and physics, Leonardo had already laid the foundations of the life sciences, dissecting corpses to study the structure and workings of the human body; both men constructed numerous mechanisms (Galileo the pendulum clock, Leonardo giant catapults and war machines). What did they have in common besides their sheer genius? In short, what makes a scientist? This is one of the first questions under debate there in Vancouver: what are the ingredients that go into the building of a scientific mind? I've made a personal selection of some of the main ones in Slide1:

Some are less obvious than others, but all are important. Where does an appreciation of BEAUTY come in, for example? In Science, beauty is often associated with the extreme SIMPLICITY of principles that can be expressed in a few words, but which provide a 'platform' on which some great edifice can be built. One example is the fact that the number of objects in a collection does not depend on the order of counting; another is that the only way of distinguishing left from right is by pointing; and more generally there are 'symmetry principles' which tell us that the properties of an isolated object must be unchanged when it is simply put in a new position in space. Yet another is the fact that heat never flows, in Nature, from a cold object to a hotter one–which leads to the famous Second Law of thermodynamics, and with it to large parts of Chemistry and Biology.

Such facts, usually taken as 'obvious' or 'self-evident', have profound consequences in Mathematics and Science – foreshadowed in Galileo's claim (in 1623) that "The book of Nature is written in mathematical characters". Incidentally, Galileo's conclusion that the Earth moves around the Sun (not vice versa) had been anticipated by Leonardo - sixty years earlier (and twenty years before Copernicus) - the mathematical argument had to wait for Galileo, but the intuition was shared by both the artist and the scientist.

Other big questions for this colloquium are, firstly, how can such attributes of the ‘scientific mind’ be nurtured and developed; and, secondly, why are they important also for the non-scientist?

On the first, I can speak from personal experience: when I was a small boy my grandfather, who was a watchmaker, used to give me old clocks to take to pieces, clean and put together again – a demanding and instructive exercise for an 8-year old. I learnt what makes a clock tick long before, as a physicist, I began to think about what makes the Universe tick! And on the way I learnt many things about scientific method, including the notion that science is all-embracing: boundaries between the disciplines are artificial and scientific method strays into many other fields. I also ran into the “two cultures” divide at an early age, having to choose between Fine Art (for which I had a passion) and Physics (which was to become my enduring love). They are closely related, I believe, through that shared appreciation of beauty.

- Objective and impartial observation of the facts
  - essential in Science, may be difficult to achieve in every day life, but it is something we should aim for.

- Questioning and the role of hypotheses
  - the latter are only conjectures, based on experience, and are thus *provisional*. If they lead to conclusions in conflict with experience they are rejected; if not, they may be accepted as ‘principles’. Science is in that sense unashamedly *pragmatic*, rather than *dogmatic*. It is also a *self-correcting* discipline: always open to revision.

- Belief in the irrelevance of the observer
  - the results of a given experiment should not depend on who performs it, or on where and when it is done. Besides being the starting point of Relativity Theory, this is a principle to be respected more widely. Race, sex, country, century are truly irrelevant in Science!

If we could all learn these lessons early in life (as most of our politicians and statesmen never do!) the world would perhaps be a better place. (Whoever remains in doubt as to the sheer folly of the human race should read John Avery’s penetrating analysis of the disparity between progress in Science and in the ‘humanities’, published in his book “Space-Age Science and Stone-Age Politics”).

When I was young there were, broadly speaking, very few basic disciplines in Science: Mathematics, Physics, Chemistry (the ‘exact’ sciences) and the ‘descriptive’ Sciences, like Biology (nowadays the ‘Life Sciences’) and Geology (now the ‘Earth Sciences’). Today there are very many more, as a result of ramification and diversification, and one of the great problems of current science is how to keep them all in perspective – how to maintain a truly global vision in which all are seen as related and dependent on the same fundamental principles.

The study of what we at LDI have called ‘Basic Science’ can, I believe, help us to develop that vision. In the few remaining minutes I want to give a brief sketch of the first five books in the Series.

Slide 2 shows the titles of the first five books, while Slide 3 shows the cover designs produced by Angel Sanz.

BASIC BOOKS IN SCIENCE

Book 1. Number and symbols
— from counting to abstract algebras

Book 2. Space
— from Euclid to Einstein

Book 3. Relationships, change
— and Mathematical Analysis

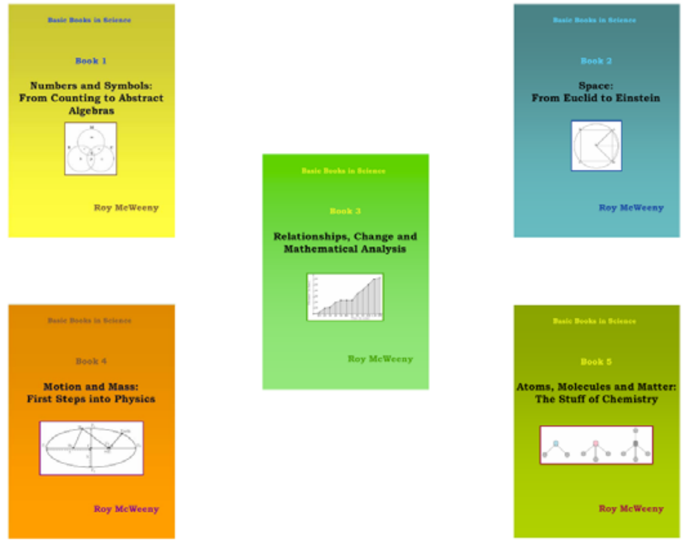
Book 4. Mass and motion
— first steps into Physics

Book 5. Atoms, molecules, and matter
— the stuff of Chemistry

Available for free downloading from the website

<www.learndev.org> (see 'For the Love of Science')

Slide 2



Slide 3

The next two slides give a brief glimpse of the contents of Book 1 (Slide 4), together with the 'Looking back' pages from the end of the book, which show what has been achieved (Slide 5 below and Slide 6 on the next page).

Book 1: Contents

Chapter 1 About numbers Why do we need numbers? Counting: the natural numbers The naming of numbers

Chapter 2 Combining numbers Combining by addition Combining by multiplication

Chapter 3 Inventing new numbers Negative numbers and equations Numbers in a picture – vectors More new numbers – fractions

Chapter 4 The decimal system Rational fractions Powers and their properties Decimal numbers that never end

Chapter 5 Real and complex numbers Real numbers and series Fields - complex numbers

Slide 4

Book 1: Looking back –

Chapters 1 and 2: all that you learnt as a child, without really understanding. Now you know what it *means*. You use *any* symbols to stand for numbers and then it's 'algebra'

Chapter 3: you met equations, containing a number you don't know (call it 'x'), along with the integers (1,2,3,...), and could *solve* the equations, to get new numbers $(0, -1, -2, \ldots)$. Then, using *pictures* you got the idea of 'fractions'.

Chapter 4: Between any two fractions there are millions of other numbers! An 'irrational' number is defined only by a *recipe* that tells you how to reach it – and it must be included!

Slide 5

Chapter 5 admitted the last 'new' number, called the "imaginary unit"(i), with the property $i \times i = -1$ (*not* 1). And when i is added the number field is extended to include both 'Real' and 'Complex' Numbers. Nothing else is needed! – the number field is *closed*.

Chapter 6, however, showed how symbols can be used to stand for other things besides numbers – *operations*, like moving objects in space; or even just for arguing about things, as in *logic*!

Slide 6

Book 4: Contents

Slide 7

The remaining slides (Slide 7 above and Slides 8 and 9 below) contain similar information on Book 4 (First steps into Physics).

Book 4: Looking back –

You started this book knowing nothing about Physics. Where do you stand now? Building only on the ideas of number and space (Books 1 and 2) and simple mathematical relationships (Book 3), you've come a long way:

Chapers 1 and 2 showed you how to build physical *concepts* from your own experience of pulling and pushing, working and using your energy. You know about force, mass, weight, and how things move; and about Newton's famous laws. You've learnt that energy is *conserved*, it doesn't just disappear – it changes from one kind to another.

Chapter 3 extended these ideas to the motion of a **particle**, acted on by a force and moving along any path. You learnt how to calculate the path of the Earth as it goes round the Sun, using only simple arithmetic and the same laws that worked for a

Slide 8

small particle. Amazing that it came out right, predicting a year of about 360 days!

Chapter 4 showed how that could be: a big body is just a collection of millions of particles, all following Newton's laws. You learnt about the **centre of mass**, which moves as if all the mass were concentrated at that one point; and about **momentum** and **collisions**.

Chapter 8 brought you to the present day and to problems of the future. You found that *mass is a form of energy* and that *in theory* a bottle of seawater, for example, holds enough energy to run a big city for a week! – if only we could get it out! This is the promise of **nuclear energy**.

Slide 9

A 2-page presentation of the Series "BASIC BOOKS IN SCIENCE" is available 'on the table' (see Annex to this document) along with specimen copies of Book 3 (Relationships, change, and mathematical analysis) in conventional paperback form (electronically available at http://www.learndev.org/dl/Science/BBS3.pdf). We have a long way to go: with Book 6 it will be time to start on the Life Sciences, in which I have no special competence, and then there will be the Earth Sciences, and so on. Perhaps we'll need twenty or thirty more books, each being a small module covering a well-defined sector of science in a serious but non-highbrow way, along the lines of those already written. So besides thanking you all for your patience and attention I'd like to end by asking your help – with proposals for extending the Series, for translating existing volumes or writing new ones, or simply for making constructive comments and suggestions.

Text version, 6 June 2007. Roy McWeeny, Series Editor (mcweeny@dcci.unipi.it)

ANNEX

Basic Books in Science

Science as a Creative Adventure of the Mind

Basic Books in Science

Science as a Creative Adventure of the Mind

A Presentation of the Series

In many parts of the world, Science Education is in crisis. In countries where there is a severe shortage both of material facilities (schools, laboratories, equipment) and of well qualified science teachers, this is understandable. But in 'scientifically advanced' societies it is not; and we must ask why.

In the UK, for example, there is a widespread disenchantment with science. The 'hard sciences', such as Physics and Chemistry, which depend heavily on Mathematics, have been hardest hit as more and more students turn towards disciplines which depend mainly on verbal expression and virtually exclude mathematical argument. One reason is surely that the symbolic languages used so widely nowadays in science are not learnt at an early age, as more conventional languages are. This modern departure from traditional forms of discourse and argument gives rise to new challenges in teaching.

Even forty years ago, the literary scholar and critic George Steiner wrote

> "There is a widespread retreat from the word: a displacement of verbal statement, of primarily verbal consciousness. Language no longer covers as much of our experience as it used to. It no longer covers it as exactly or as richly. As the sciences become more and more mathematical, as the language of mathematics, symbolic notation and coding, grow subtler, the authority of speech and of our traditional concepts of syntax is coming into a very critical and complex state ... Our words tell us less of the world and other languages crowd upon our bewilderment."

He lamented the passing of the nineteenth century, when the tremendous advance of science was seen by the historian and the literary scholar not as a threat but "a glorious parallel adventure".

And yet little has been done to reverse the trend. Science is no longer seen, by many, as a creative and cultural enterprise but rather as something quite foreign to more 'human' pursuits.

In today's world this situation is no longer acceptable. We should try to bring an understanding of science and its symbolism within the reach of everybody; without such an understanding, members of society will be unable to participate fully in shaping their destinies – destinies that will depend increasingly on the progress of science and our awareness of where it is taking

us. And this will require a radical overhaul of the teaching/learning interface. Basic Books in Science is one of many attempts to meet this challenge.

Every book in the Series will start 'from the very beginning', so as to be accessible to anyone, anywhere, who wants to know about Science and is prepared to start from nothing and work hard. The books are addressed first of all to readers of immediate pre-university age; but more generally to the many who 'missed the boat' and may feel it is now too late to start. For anyone who can be excited by some of the most stunning achievements of the human mind it is never too late!

Each book will be a small 'module' of Science, typically containing around 150 pages on a compact and well defined theme: the themes may be trans-disciplinary, cutting across traditional boundaries, but will be carefully chosen to give maximum coherence within the Series. Examples are Book 1 "Number and symbols – from counting to abstract algebras" and Book 2 "Space – from Euclid to Einstein". Taken together, the books of the Series will provide a rudimentary science library leading up to university entrance level (and sometimes beyond). Individually, each book will contain material for study, either privately or with help, over a period of 4-5 years, graded according to growing maturity of the reader.

Besides being 'thematic', the treatment is innovative, *not* following the traditional (schoolroom) pattern with its emphasis on science as a predominantly experimental discipline. It can be argued instead that the required 'input' from the laboratory is often quite small and that many hours of practical work, using costly equipment, are not essential to gaining an understanding of science and scientific method.

A primary aim of the Series is to show how large parts of Mathematics and the Physical Sciences can be built up from nothing more than a few notions about *counting* and *measuring* (e.g. distance, with a metre rule, and time with a clock), together with a few very primitive observations – like Galileo's experiments with falling bodies.

The rest is indeed largely **a creative adventure of the mind**, in which more and more is discovered just by *thinking* about what one knows already. Even though Science has its roots in observation and experiment (and the validity of any theory rests on the agreement of its predictions with observed 'reality') we have chosen to stress the theoretical aspect of so much of science because we find it appealing, beautiful and exciting and hope to share that excitement with others.

Pisa, 23 May 2007 Roy McWeeny, Series Editor