Our Human Condition "From Space"

Alan Kay

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Viewpoints Research Institute, 1209 Grand Central Avenue, Glendale, CA 91201 t: (818) 332-3001 f: (818) 244-9761

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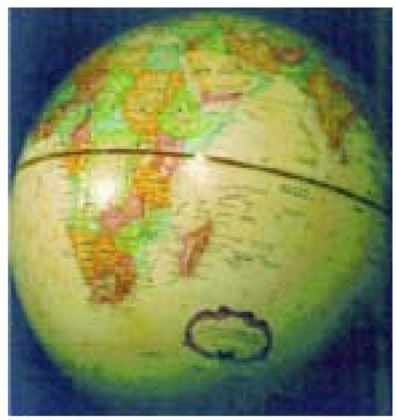
My favorite examples of early science, and a wonderful general metaphor for what science does, are the attempts at highly accurate map-making started by the Greeks, then lost for a thousand years, and then taken up again starting in the 15th century. By the end of the 1700s, people delighted in being able to buy a pocket globe of "The World As Seen From Space". 200 years later, we went out into space, looked back at the world, took pictures of it, and saw just what the 18th century map makers had already found out.



All scientific processes and knowledge have this character: they are attempts to "see" and represent things very accurately from vantage points that are not part of our normal commonsense guesses about the world -- to "make the invisible somewhat visible". For most of human history our theories about ourselves and the world we lived on were mainly in terms of unsubstantiated beliefs rendered as comforting stories. A few hundred years ago we learned a new kind of seeing that allowed us to perceive the physical world as if "from space" with far fewer prejudices in the way. In the 21st century we need to not only do this for the physical world, but also to understand our whole human condition as if "from space", without the comforting stories, but with deeper understanding of how to deal with our natures and nurtures.

Maps, as with all of our representations for ideas, are quite arbitrary and don't automatically have any intrinsic claims to accuracy. For example, here are 3 maps. The first is a map from the Middle Ages, the second is a map from Tolkein's "Lord of the Rings", and the third is a map of the Mojave Desert. The medieval "T-O" map shows the world as they thought "it had to be", and includes the Garden of Eden (to the Far East at the top). The Mediterranean (the middle of the world) is the vertical of the "T", Jerusalem is at the center of the world at the joining of the "T", and the boot of Italy is just a bulge. The Tolkein map was made up in careful detail to help readers (and probably the author) to visualize the fictitious world of the Hobbit and Lord of the Rings. The map of the Mojave Desert was made last year using both advanced surveying methods and satellite imagery to guide the placement of features.

It is important to realize that from the standpoint of traditional logic, none of these maps is "true", in that none of them are in exact one-to-one correspondence with all the details of what they are trying to map. In other words each of these maps is a kind of story that is written mostly in images rather than words. Within a map we can do perfect logic -- so for example, if Rome is North of Alexandria, and Paris is North of Rome then Paris is North of Alexandria. This internal logic works perfectly for all three maps. Mathematics is also a kind of mapping system that is set up to be completely consistent within itself -- in fact, it includes the making of maps like these ("Earth Measuring" in Greek is "Geometry"). It's when we try to relate the maps to what they are supposed to represent "outside" that we run into difficulty and find that none of them are "true" in the sense of the truth that can obtain inside a map. But if you were dropped into the Mojave Desert, which "not-true" map would you choose to take with you? Many flavors of "false" really makes a difference in modern thinking!

From our standpoint, the reason to teach "the new thinking" that has flowered in the last 400 years is not to provide more technical jobs, or to "keep our country strong", or even to make better citizens. These are all good results that are byproducts of the new thinking, but the real reasons have to do with sanity and civilization. If the maps in our heads are unlike "what's out there" then we are at best what Alfred Korzybski termed "unsane". Our definition for actual insanity is simply when the maps in our heads, for whatever reasons, become so unlike "what's out there" (including what's in other people's maps) that it is noticeable and sometimes dangerous. Since we can't get maps to be exactly true, we are always somewhat unsane with respect to the physical world. Since our actual internal maps are not directly sharable, we are even more unsane in relation to each other's mappings of the world including us. Because we think in terms of our internal maps -- a kind of theatrical presentation of our beliefs back to ourselves -- it is not too far a stretch to say that we live not in reality, but in a waking delusional hallucinatory dream that we like to call "reality". We definitely want to construct the "least false" version of this that we can!

Civilization is not a state of being that can be reached, nor the journey, but it is a manner of traveling. To me the most interesting and remarkable -- even amazing -- thing about science is that it is done by us even though we are creatures who only have stories of various kinds inside our heads and are much more set up to be interested in charging sabretoothed tigers than in centuries long climate changes. But the process of scientific thinking is able to deal with many of our own inabilities to think and other flaws in a strong enough manner to still come up with ever more accurate mappings of more and more complex parts of our universe. This is why we need to help all children in the world learn how to do it.

But why then are science and its mapping language - mathematics - deemed to be hard to learn? I believe that it is not because they are so intrinsically complicated, but rather they are amazingly simple yet very very different from normal human commonsense ways of thinking about things. It is gaining this quite unusual point of view about "what's out there?" and what it means to find and claim knowledge about it that is the main process of learning science. One way to look at this is that part of what has to be learned is a new kind of commonsense -- Alan Cromer calls it "uncommonsense".

And, just as it doesn't require more than a normal mind to learn these ideas, it also doesn't require any major outlay of funds, though many people like to give the excuse that "science teaching isn't happening because we don't have computers, scientific equipment, books, etc.". Science is about 400 years old now, and we've had commercial personal computers for a little more than 20 years, so there were about 380 years in which science and math were learned without high tech. Some of the most important discoveries were done before the industrial revolution with very little equipment.

I think what is mainly lacking are adults who understand science who want to work with children and teachers regardless of the funding. Shame on my own profession! Most of us stay in the labs and away from children, parents, teachers and schools.

How can we learn science with "no money"? First and foremost, we have to learn how to observe and be interested in phenomena in a noncategorical way, i.e. we don't want to dismiss things after we've merely learned their names -- there's a sense in which most things become almost invisible after we can recognize them and recall their names. So we have to find ways "to make the invisible visible", to avoid "premature recognition". Science is all around us and much can be revealed just by being more careful about what we think we are seeing.

One of the ways to do this is by learning how to draw. As Betty Edwards (of "Drawing on the Right Side of the Brain" fame) points out, learning to draw is mostly learning to see (as opposed to learning to recognize). For many things we need to find ways to postpone quick recognition in favor of slower noticing.

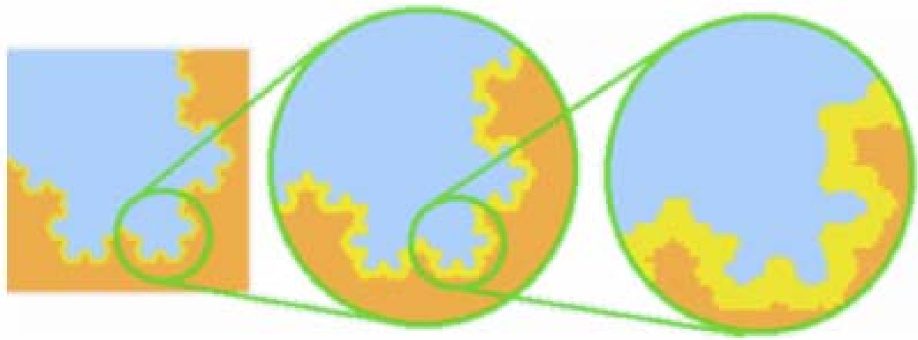
This is somewhat different than the "art part" of the visual arts in that we are trying to mostly express the visual details of "what's there" rather than what we feel about it, but they are not at all exclusive. As my grandfather once remarked in an article he wrote for the Saturday Evening Post in 1904 about whether photography could be art: "Art enters in when we labor thoughtfully with some goal in mind; that is, when we cut loose from actions that are merely mechanical". The feelings will appear in any of our carefully made creations.

Another good example of "high-noticing low-cost" is the measuring of the circumference of the bicycle tire project for 5th graders. Much of the philosophical gold in science is to be found in this noticing activity.

The students used different materials and got different answers, but were quite sure that there was an exact answer in centimeters (partly because schooling encourages them to get exact rather than real answers). One of the teachers also thought this because on the side of the tire it said it was 20" in diameter. The teacher "knew" that the circumference was pi * diameter, that "pi is 3.14", and "inches times 2.54 converts to 'centimeters' ", etc., and multiplied it out to get the "exact circumference" of the tire = 159.512 cm. I suggested that they measure the diameter and they found it was actually more like 19 and 3/4" (it was uninflated)! This was a shock, since they were all set up to believe pretty much anything that was written down, and the idea of doing an independent test on something written down had not occurred to them.

That led to questions of inflating to different pressures, etc. But still most thought that there was an exact circumference. Then one of us contacted the tire manufacturer (who happened to be Korean) and there were many interesting and entertaining exchanges of email until an engineer was found who wrote back that "We don't actually know the circumference or diameter of the tire. We extrude them and cut them to a length that is 159.6 cm ± 1 millimeter tolerance!

This really shocked and impressed the children -- the maker of the tire doesn't even know its diameter or circumference! -- and it got them thinking much more powerful thoughts. Maybe you can't measure things exactly. Aren't there "atoms" down there? Don't they jiggle? Aren't atoms made of stuff that jiggles? And so forth. The analogy to "how long is a shoreline?" is a good one. The answer is partly due to the scale and tolerance of measurement. As Mandelbrot and others interested in fractals have shown, the length of a mathematical shoreline can be infinite, and physics shows us that the physical measurement could be "almost" as long (that is very long).



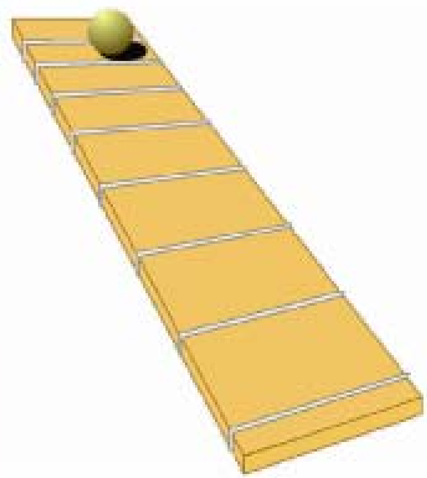
There are many ways to make use of the powerful idea of "tolerance". For example, when the children do their gravity project and come up with a model for what gravity does to objects near the surface of the earth, (see http://www.squeakland.org/pdf/etoys_projects/Project10.pdf) it is very important for them to realize that they can only measure to within one pixel on their computer screens and that they can also make little slips. A totally literal take on the measurements can cause them to miss seeing that uniform acceleration is what's going on. So they need to be tolerant of very small errors. On the other hand, they need to be quite vigilant about discrepancies that are outside of typical measuring errors. Historically, it was important for Galileo not to be able to measure really accurately how the balls rolled down the inclined plane, and for Newton not to know what the planet Mercury's orbit actually does when looked at closely.

Next year (2004) is the 400th anniversary of the first time in history that a good model was made of what happens when a body falls near the surface of the earth under the influence of gravity. Galileo didn't have home video cameras and computers and Squeak to come up with the model. He did his discovery "with no money" by being very diligent about observation and noticing until he found a way to pin down what was happening crisply enough to map it with mathematics.

How did he do it? There doesn't seem to be an absolutely definitive answer to this, but there are many stories about it which have been pieced together from Galileo's notes and writings. Galileo's father was a professional musician and Galileo had an excellent reputation as a musical amateur on a number of instruments including the flute and the lute.

He had been doing many experiments with inclined planes using uniformly sized balls made from different materials and having different weights. He discovered that same sized balls of different weights appeared to go the inclined plane at the same rate of increase of speed regardless of angle.

One day he may have for fun idly rolled a ball or two down the neck of his lute. You can see that the frets of lutes and guitars are not evenly spaced. At some point he noticed that the clicks of the ball on the frets were almost regular and realized that the wider spacing of the frets was compensating for the increase in speed of the ball. Now a wonderful thing about lutes is that, unlike guitars, their frets are made of the same gut that is used from the strings and are simply tied on. So Galileo could move them. He started to move them until he could hear an absolutely regular sequence of clicks (at some point he probably started to tie the fret material across his inclined plane). When he got perfectly regular clicks, he measured the distances and found that the increase of speed (the acceleration) was constant!



One of the important conclusions here is that there are many interesting real science probes that can be done with materials at hand if the teacher understands the real science. This is one way to do this investigation "with no money", and rolling a toy truck down the inclined plane carrying a baggie of ink with a pinhole, is another.

Don't let the lack of a computer or equipment slow you down. Science and math are all around us. The world we live in is a vast lab full of equipment, if it can be noticed. There are free public libraries even in the most disadvantaged parts of the US that contain books about how to do all of this: the knowledge doesn't cost money, but it does cost time and interest and focus.

You are reading this book because you are interested in all these issues -- perhaps you found it in a free public library -- whether or not you can afford a computer today. If you can't, there is still much you can do, just as there is so much real music that can be done with children without formal instruments. If you can afford the instrument -- musical or computer -- then you've just gotten wonderful amplifiers for your musical and mathematical and scientific impulses.

The computer quite naturally turns the math back into phenomena, thus providing a more complete full circle of "putting together" added to the "taking apart" nature of science. This is one of the most important uses of computers in adult science and engineering and thus the children and adults are strongly joined in the same art and sport, just as children's music is real music, and children's baseball and tennis are real versions of the sports.

A further insight is that the range and depth of constructions that the children can carry through are vastly extended by using a suitable computer environment. Many researchers have found that children are capable of deeper thoughts than they can easily build: for example, they can think very deeply about how robots and animals can make their way in the world and create truly subtle and profound programs on the computer that bring this ideas to life in a way that is far beyond their abilities to construct physical versions of these ideas at their age.

In a few years the computers themselves will be almost free and will be part of a truly global communications network. So all the stuff described in this book is almost within reach of every child on the planet. But we still have to find ways to not forget what is really important here.

The most critical distinction we have to keep in mind is that between "doing real science" and "learning about what scientists have done". This is similar to the distinction between "Music" and "Music Appreciation". The latter are worthwhile in both cases, but both quite need the learning of the real process in order to understand what the "Appreciation Knowledge" really means. For example, there are no important differences between being given a "holy book" full of assertions and being asked to memorize and believe them, and being given a "science book" full of assertions and being asked to memorize and believe them. As with the difference between two values of logic (true and false) and the many valued logic of science (lots of worthwhile falses) the difference between what science means when it says "we know that ..." and what previous knowledge systems mean by this could hardly be larger. When science makes a claim about "knowing", it is so different from previous uses that it should not have tried to reuse "know" as the word for this, because what is meant is: "we have an excellent map-model for this that works thus and so with this amount of tolerance and doesn't map as well as we'd like here and there, and by the way, here's how you can help check this out and make your own criticisms, etc.".

I hope that the projects presented in this book and what you've read so far will convince you that these activities are not only "math and science", but deep, real, and important aspects of mathematics and science.What if more issues than those of the physical world were thought about in this slower, suspended-perception, skeptical, careful, powerful, and map-and-model building manner? If you think that things would be vastly different and improved for the benefit of all humans, then please help children learn to think much better than most adults do today.