How Much Science Does a Citizen Need?

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While many believe that there's a set of basic scientific facts that people should know, they are spectacularly unsuccessful at being able to nominate just what those facts should be.

Carl Sagan thought that science was fundamental: "We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. This is a clear prescription for disaster. It's dangerous and stupid for us to remain ignorant about global warming, say, or ozone depletion, toxic and radioactive wastes, acid rain. Jobs and wages depend on science and technology."

But there are dissenting voices. George DeBoer examined the history of the science school curriculum in the USA. Now deputy director for Project 2061 of the American Association for the Advancement of Science, DeBoer wrestled with the issue of what science should be taught and why. He looked at the arguments put forward for the teaching of science by people in government, industry and defence.

In his frequently cited paper published of 2000, DeBoer pointed out that "people with extremely limited understanding of science function very well in society, many of them at the very top levels of their professions. There is no reason to believe that the national security, economy, democratic way of life, and science prominence are threatened by the low level of scientific and mathematical literacy in the general population."

His comment would not find much favour in Australia, where leaders in government, industry and academia have long urged students to gain the qualifications for science-based careers. We are, as our Prime Minister is fond of pointing out, living in exciting times, where nimbleness is essential and innovation is king.

Just before he retired last year, Australia's Chief Scientist Ian Chubb echoed Sagan's sentiments. His view is that it's important that the general population understands the way scientists work. Not everyone will become a scientist, but people need an appreciation of the fundamentals in order to participate, for instance, in debates on climate change. According to Chubb: "We live in a world utterly reliant on science to fuel its industries and provide for its people. In the future, science will only become a bigger part of our lives, and the impacts will

touch us all... We need therefore to equip as many of our future citizens as possible to understand how science works, its methods and its ethics; and to be able to make better informed judgements." (http://tinyurl.com/hbv6vcv)

While DeBoer said it is not essential that the general population have knowledge of science, others regard this as crucial: to take advantage of the advances modern science creates, for employment and national prosperity, and to participate intelligently in community discussion.

So views are divided. But if we decide to accept the argument that everyone needs a working knowledge of science, the question becomes: what science do they need to know?

Should they understand whether the sun goes round the Earth, or vice versa? Be able to explain how aeroplanes fly, or the causes of climate change? Or to know the Second Law of Thermodynamics, which CP Snow nominated as fundamental in his *Two Cultures*?

Is there a tipping point for scientific literacy that causes economic activity to decline, society to make poor choices on issues such as vaccination and climate change ... and for superstition to flourish?

Again the experts are split. Some claim there are fundamental facts that citizens should know and that these facts can be tested, and personal and national figures for "scientific literacy" be determined.

Jon Miller, for instance, first defined and then began measuring "scientific literacy" in the US in 1979, when he conducted a survey asking simple questions such as whether the Earth goes around the Sun. In the ensuing 37 years, tests based on Miller-type questions have run in over 40 countries (including at least once in Australia), and including Europe's Eurobarometer.

These surveys have allowed international league tables to be drawn up ("Romania moves up the scale in science literacy while Korea slides!"), and progress – positive or negative – to be measured over time.

Others in this field think that knowing facts is less important than acquiring certain skills. Susannah Priest, editor of the prominent American journal *Science Communication*, is a proponent of this approach: "No list of scientific facts quite captures what we hope citizens will bring to the disentanglement of legitimate but messy science from other sorts of arguments and claims. Citizens often need skills that will serve them well when the facts are not yet clear, even to scientists."

In her view people need the ability to work out quickly the credibility of a scientific paper or report, using what she calls "heuristic clues" to sort the scientific wheat from the chaff. Is the author from a reputable institution? Was the article published in a recognised outlet? Does it conform to established theory or propose way-out ideas? This ability, she says, is far more useful than a command of facts.

Prof Chris Bryant of the Australian National University's Centre for the Public Awareness of Science (CPAS) has a slightly different emphasis. People need to be able to find information when they need it, and that is more important than collecting facts: "What I would like [people] to know is how to access the science that they may need from time to time. People are very good at educating themselves when the need arises."

The University of California's *Scienceline* has a philosophical difference with the fact-based approach. *Scienceline* is a public forum where people ask questions of a panel of UC scientists, and in a recent post: "To even ask the question of what 'facts' in science should people know puts science in the corner where it does not belong, that of being perceived as just a collection of facts."

I tested these arguments with the science communication fraternity, first at a seminar at CPAS, and subsequently in an international survey publicised through the Public Communication of Science and Technology Network.

When asked their primary professional aim, the 118 respondents most frequently selected: "provide information for the public through websites, publications". Other aims included training scientists to communicate, understanding better communication processes through research, understanding the concerns and preferences of the public on particular issues, and encouraging students to study science.

Only 15% aimed to link science with industry, or to change practices in industry.

The first survey question was: "Do you think there is a set of basic scientific facts that people should know?" Two-thirds supported this proposition, with the other one-third split equally between "No" and "Don't know".

Those who responded "Yes" were then asked to list or describe these facts. Their answers fell into four categories, with most nominating a broad understanding of science. Some specified a detailed list of facts, subjects and principles:

> *Theory of evolution, basic genetics, basic Newtonian mechanics, basic principles of thermodynamics (heat, conduction), constitution of atmosphere, basic functions of central organs in the body, basics of nutrition and health, basic math – numerical literacy, basic technological literacy.*

Others in this category agreed with the need for a broad understanding but were less specific. They often used the phrase "a basic understanding of ..." followed by a list of disciplines and areas of knowledge:

I think people should understand the basics of most fields. Mechanics, thermodynamics, genetics, etc etc. Just knowing the basics gives you insight into the importance of talking to experts when something falls outside your knowledge.

Basic principles of evolution; some principles of mechanics, optics & electricity; carbon & water cycle; medical knowledge related to vaccination & antibiotics —> mostly stuff with impact on everyday life.

Their views endorse a general science course at high school or undergraduate level.

The second largest group wanted to combine facts with an understanding of process:

On the side of facts: minimum basic knowledge of chemistry, physics and biology of ordinary daily things; on the side of "dealing with facts": a basic knowledge of the way science works; reasonable knowledge about was [sic] is a valid scientific claim and what seems bogus (even some scientists don't); capability of distinguish [sic] what can be important or not (also).

As facts, the evolution, and the urgency of learning on the climate change, global warming, pollution, and their respective links to the combustion of fossil fuels and other human activities. But it is important too that people learn the rules and processes of science (the laws of science but also the scientific method), as well as critical thinking.

The third group were reluctant to nominate a set of "basic facts". While some "core knowledge" was important, curiosity and being able to "test things yourself" were equally important:

I don't like the idea of "basic scientific facts" but some core knowledges and attitudes to the physical world are needed in each society. It helps people to have some basic level of physics – gravity, inertia. Understanding forces and geometry for building things. Basic biology for food safety and personal hygiene – bacteria, viruses and toxins.

The fourth group focused on the practical knowledge needed to navigate a way through life: boiling tap water to kill bacteria or germs; principles of hygiene and nutrition; practical skills like how to extend the battery life of mobile phones.

People should know that expired food can be eaten a few days after expiration dates because the preservatives are still there in the food, and there is lack of oxygen to grow bacteria or germs quick enough to make the food go bad… People should learn about how dementia can affect different old people in different ways, to look out for parents, e.g. some elderly may have problems with arithmetic, some may have problems distinguish an apple and a christmas tree decorations.

The breadth of these responses is considerable. Every discipline and field of study was nominated as fundamental in these wide-ranging responses. Although two-thirds of all respondents agreed with the proposition that there is a set of basic scientific facts that people should know, they proved spectacularly unsuccessful at being able to nominate just what those facts should be. (Not one respondent nominated as essential a knowledge of the second law of thermodynamics, the topic CP Snow regarded as a litmus test of scientific literacy in his famous *Two Cultures* lecture of 1959.)

The missing one-third – the respondents that didn't agree with the proposition – was split equally between those who disagreed and the "don't knows".

To an outsider, this wide diversity of views suggests a degree of confusion. Do citizens need to know facts about science in order to consider, debate, decide on scientific issues and the direction of society, or not?

Respondents were more sympathetic to the idea that citizens should understand the way scientists work – the "scientific method". Nearly 90% agreed with that statement.

Society can survive and prosper as long as some members have "the knowledge" to make industrial and environmental advances. But what if the proportion of the knowledgeable declines?

Is there a tipping point for scientific literacy that causes economic activity to decline, society to make poor choices on issues such as vaccination and climate change, not enough skilled people to fill scientific positions, and for superstition to flourish?

A BioLogos poll of 2014 reported that 56% of Americans believe that Adam and Eve were real people. Not one of the 17 Republicans contesting the Presidential primaries believed that human activity caused climate change. And yet the US continues to thrive.

Perhaps society will survive as long as a reasonable proportion of the population has some knowledge of science and its processes.

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