Online Course in Science Journalism

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Lesson 5 - What is Science?

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5.1 Introduction

Science has transformed our modern world deeply and spectacularly. Science has shaken up every walk of life so much that it is impossible to escape its grasp, for better or worse.

In this lesson, we will discover what science is. First, we will review the basic principles and means that have made science the best way to define reality (Section 5.2). We will then introduce to you a few 20th century thinkers that have highlighted the limits and dangers of science (Section 5.3). We will end the lesson with a look at very specific aspects of science as it is practiced today (Section 5.4).

By the end of the lesson, you should be able to:

1. Understand what science is and what it is not;
2. Be aware of its strengths but also of its limitations; and
3. Ask its practitioners questions about its quality, with aplomb.

5.2 Different paths to knowledge
5.2.1 What is knowing?

In this part of the lesson, you will learn about the method of producing scientific knowledge and you will see how to distinguish science from other kinds of knowledge-gathering, including science journalism.

Science begins with: "I want to know"

To "know" is so natural and so straightforward that trying to define what it means may look strange. In fact, explaining what we mean by to "know" can be extremely complex since it can have many meanings.

Within the context of science, to "know" means to exercise curiosity, **to observe** and **collect sufficient** information and intelligence to **identify, distinguish and describe the different features** of reality in a most truthful way. This reality can be real, virtual, concrete, natural, artificial, abstract, physical or metaphysical. **Exercising curiosity produces knowledge.**

5.2 Different paths to knowledge
5.2.1 What is knowing? (continued)

Objective knowledge is when we analyse things as they are, keeping ourselves out of the picture. It is a kind of enlightened way of knowing and assessing, and brings with it a kind of power to reject, refute, accept, adopt, keep some distance, and even modify the way things are. Knowledge comes with the obligation to ask questions and to challenge our ignorance. **To "know" something makes it possible to apply reason, to observe and analyse it.**

Different from knowledge are beliefs. **Beliefs are a way to explain the universe by endowing it with capabilities, qualities, sentiments and emotions.** Beliefs give an intrinsic significance to things. As an example, for certain individuals, the number 13 is considered a bad omen. In some cultures, the rainbow is a warning of bad things to come, it is God's sword; while in others, it might indicate where a treasure is hiding, and is therefore a good omen.

Beliefs require immediate acceptance and commitment; beliefs build roots in our most intimate self. Religious belief is most often a personal and intimate quest for truth. The statements and propositions that come with beliefs require that they be taken at face value. Religious knowledge requires acceptance of facts and statements that cannot be demonstrated. The existence of God is not an object of science but a belief since there is no way to demonstrate or negate its existence. Buddhism, Judaism, Hinduism, Christianity and Islam are but a few of the great religions that have shaped and still shape humankind's history.

5.2 Different paths to knowledge
5.2.2 Day-to-day or common knowledge

What is common knowledge? And how is it different from scientific knowledge?

Day-to-day knowledge is called **common, sensible, primary or immediate knowledge.** The explanations it provides are based on broad statements, mostly from oral tradition. These explanations are received without question. They are often quick and crude generalizations. They are based on simple observations: we say that the sun rises and sets; we see that the sky is very "high." Common knowledge does not plan to change things.

Common knowledge arises from our daily dealings with our environment and the way our cultures describe the universe. It is constructed and transmitted by our families, relatives, friends, neighbours, partners, tribe or community. It is this human community, our dearest community, which shares its ways of life, its joys, worries, pains, wishes for the future, perception of the present, and what it remembers from its past and its traditions. And that common knowledge involves superstition.

Despite the limitations of the common knowledge of our tribe or community, life would be impossible without that knowledge. We would be rationalizing non-stop, hesitating, and always deciding too late.

Common knowledge exists in every culture and civilisation. Each one of us begins with common knowledge in our daily lives and interactions with fellow citizens. Scientists themselves start with common knowledge, but eventually go beyond it.

5.2 Different paths to knowledge
5.2.3 Beyond the day-to-day stuff

Systematic knowledge requires going beyond the well-travelled and easily accessible pathways. It does not claim to be definitive. It accepts being questioned. Answers are found by digging. With systematic knowledge, things and their descriptions evolve.

Knowledge asks for proof. It begets arguments. It poses questions. Nothing is taken for granted. Knowledge puts back on the table today what it accepted yesterday. It always digs as much into the unknown as into what is known. It is a perpetual quest, without taboos or no-go areas.

Systematic knowledge aims to create, imagine, and discover what we don’t know. It does not rest on tradition and cannot stand monotony. It criticizes. It examines and questions its own ways of looking, touching and feeling. Its main instrument is reason and it refutes superficiality. Systematic knowledge constantly checks the approaches it relies upon to analyse and create. It has its own method.

Systematic knowledge belongs to intellectuals, artists, artisans, authors of "works of the mind," and scientists. However, there are differences between the different ways of knowing, and scientific knowledge has its peculiarities.

5.2 Different paths to knowledge
5.2.4 Science as a means to systematise knowledge

Introduction to scientific knowledge

Science, like art, is a form of systematic knowledge but there are crucial differences between the two.

In art, systematisation of knowledge is based on individual preferences, criteria for beauty or, if you prefer, aesthetics and emotions. In science, systematisation is something different. If art is a question of taste, **science is the business of producing a truthful description of nature**. Here, to systematize means to deepen, weigh, measure, time, argue, reason, and construct logically, refusing subjectivism, putting aside one's own preferences, and keeping oneself out of the picture.

Scientific knowledge aims to understand nature and the universe in which we live through known, concrete and objective elements.

Scientists make pronouncements based on reasonable justifications. The perfect scientific approach is **demonstration**. A demonstration is a clear and full argument. In science, a demonstration is also something practical like a laboratory experiment, showing a phenomenon and establishing cause and effect. A demonstration shows results with certainty and makes generalisations possible, leading to predictions. This is the case with modern science, compared to the old sciences which, with their proximity to religion, used authority to win arguments and mainly questioned the "why" of things.

5.2 Different paths to knowledge
5.2.4 Science as a means to systematise knowledge (continued)

Modern experimental science

Modern science starts with systematic doubt or what the American sociologist Robert K. Merton calls **"organized scepticism."**

Modern science arose in the 17th century – during the period of Enlightenment – and is **based on observable facts**. Science matches facts against reality **through experiments**. This is why science needs laboratories and tools to study everything from the most minuscule particle to the whole universe. Science establishes rigorous methodologies with reliable instruments to accumulate evidence with which to prove or disprove a hypothesis. Science evaluates its own methodologies and re-examines its own proofs.

Ideally, experimental science is independent of the person making the observation or performing the experiment. It is **objective and impersonal**, and in agreement with the observed reality and other confirmed knowledge.

Science ideally gives clear, logical results exempt from ambiguity. Their validity can be verified or disproved using argument and reason (this is examined in depth in the upcoming section on Karl Popper's concept of falsification.) Scientific results have to survive tough and thorough testing. **This is scientific rationality**.

Modern science deduces truth from facts, **verified by methodical experimentation**. Experiments tell how things and phenomena measure, how much they weigh, how long they last, in which direction they are going, etc. Experiments give mathematical data.

Whereas ancient science attempted to explain the "why" of things, **modern science aims to answer the "how"** of things.

5.2 Different paths to knowledge
5.2.5 The scientific method

Before describing the scientific method, let's see what other methods are available to understand the world.

Human beings have longed to grasp nature and explain how humans behave. Amongst many approaches, **religion** provided some answers. It was seen as one way to seek truth. It claims to answer questions like: Who are we? Where are we? Where are we going? What is the purpose of life on Earth? Still today, the great religions each propose a vision of the universe from its creation to the end. The journalist who writes about science must respect religions, since they are the realm of the individual, but **must situate his or her work outside of religion**.

Another approach to providing an understanding of the world has been the **authority argument**. Essentially, it meant that if a famous and prestigious Greek thinker had said something, then it was valid forever. This happened with the works of great philosophers like Plato, Aristotle and Pythagoras, or great mystics like Hermes Trismegistua.

Nowadays, in our communities we have sorcerers, healers and marabouts who also propose their vision of the world. Many of them hold an **empirical or mystical** knowledge of their milieu. Others follow some superstitions and illusions, while still others develop parallel systems of knowledge.

5.2 Different paths to knowledge
5.2.5 The scientific method (continued)

How does science work?

Essentially, modern science establishes knowledge through the following steps:

a. Observation.
b. Experiments.
c. Explanation.
d. Generalisation and prediction.

a. **Rigorous observation**
Observing means to go through the following steps:
- Careful observation of the facts.
- Putting aside one's personal opinions.
- Abandoning speculations and prior knowledge.
- Abandoning beliefs, prejudices, expectations and passions.
- Abandoning statements of authority.
- Asking oneself logical questions.
- Proposing hypotheses.

b. **Careful experimental fact-checking**
Fact-checking is done through experiments, with the appropriate methods and tools. The objective is to check the accuracy of the observations and facts and demonstrate relationships between these observations and facts. Experimental fact-checking requires that:
- Observations be repeated in different situations by different people.
- Results be victories over ignorance without submitting to authority.
- Unequivocal relationships be shown between cause and effect.
- Results give a clear and unambiguous confirmation of truth.
- Results provide a truthful validation that is free from illusions.

c. **Careful explaining**
When scientists explain, they have to:
- Discuss any previous contradictory observations.
- Demonstrate relationships between new observations and previous observations.
- Explain why a certain cause has a certain effect.
- Make sure that there are no faults with the argument.

d. **Generalise and predict logically**
When a certain number of verified facts have been discovered, a scientist can then proceed to generalisation or induction, to use the academic terminology:
- Generalise the observations.
- Accept that the demonstrated facts describe reality.
- Make laws and theories valid for similar situations.
- Predict the evolution and future state and shape of the facts and their relationships.

5.2 Different paths to knowledge
5.2.5 The scientific method (continued)

Hard and soft sciences

The above method can be applied, in principle, to all sciences – as much to the natural sciences (hard sciences) as to humanities or social sciences (soft sciences) like sociology, psychology, political science, history, geography, theology, economy and even medicine.

However, the different steps required by the scientific method can lead to certain difficulties when applied to some of these soft sciences and their object. For example, one cannot experiment on human beings as can be done with plants and minerals. In the same way, the sciences that study society can encounter difficulty when trying to make generalisations and predictions.

In general, the basic tenets of the scientific approach remain valid, the different soft sciences using some of its methodologies more than others. As such, **the scientific method is a must in all fields of study that claim to be scientific**.

5.2 Different paths to knowledge
5.2.5 The scientific method (continued)

What science is not

Science has become a particular kind of fascinating but difficult knowledge that surpasses all other forms of knowledge, particularly because it reaches closer to truth and can be used to transform reality so much that it has shaped our modern world. It has spectacularly reshaped health, communications, housing, energy, agriculture, war, and life itself.

Our world largely exists as a manifestation of science – and could also be destroyed by it.

Modern science is nonetheless no panacea or book of magic that can solve any problem. It uses no method from the occult. Even thought some experimental results are kept secret for fear of their being stolen, scientific methods are no secret. In no way do they rely on tradition. If they stick to any tradition, on the contrary, it is to destroy anything that could become a tradition.

Though it may seem to insinuate itself everywhere and looks like taking away powers that used to belong to the gods, science is no religion and scientists are no priests of a sect. The big and costly infrastructure it may require seems to have made science the privy of some nations, but **the scientists are from no particular race, sex, age, religion, skin colour or wealth**.

Even if science seeks truth, scientific results are no definitive truth and nothing like divine commandments; scientists are on a never-ending quest and are never satisfied with their own truth. Moreover, the publication of results is an invitation to others to check them for **accuracy**.

As a human endeavour, science has its weaknesses. Errors, even fraud, happen. Some experiences are trafficked, results fabricated. It is a world with its share of rivalries, ambitions, illusions and dirty tricks, particularly regarding who was the first to invent this or that. But science's unique strength – and what sets it apart – is its ability to track errors and correct them with further experimentation.

5.2 Different paths to knowledge
5.2.6 Journalistic knowledge

The journalistic method

Since this course is aimed at working journalists, it will not go into the fundamentals of journalism.

Suffice to say that, like the work of any contemporary scientist, a journalist's work is based on the observation of facts. As journalists say: "**Facts are sacred, comments cheap.**" Like scientists, journalists strive to remain neutral and objective, since they have to put aside their own personal interests and the prejudices of their immediate community.

When collecting information and producing news, a journalist puts truth above everything. This is another common trait between scientists and journalists.

But a journalist is above all a witness; journalists report events for a public that was not there. Journalists don't publish for other journalists but for mass audiences. Journalists also don't report the bare facts. A good journalist provides the context and explains the implications for politics, education, law, justice, ethics, and the life of populations. The best journalists manage to let the facts speak for themselves. They also give a voice to key actors and make the facts intelligible.

The facts provided to the public by a journalist must satisfy certain criteria:

- **Truthfulness**: A journalist does not write fiction and does not invent facts.
- **Newsworthiness**: A news item has to bring new information that modifies the known context.
- **Meaningfulness**: Facts are weighed according to their meaning, significance, potential consequences and importance for the public.
- **Interest**: Journalists look for what is unusual, for what touches and excites the public's curiosity.

Journalists and scientists don't use information in the same way. **A scientist observes something very specific**, often a small piece of a much bigger entity. **A journalist casts his net as wide as possible** to put his story in the widest context. To be sure not to mislead the audience or the readers, a journalist brings in other domains of knowledge and other actors. As an example, a medical story will include information and facts about the economy, geography or sociology.

5.2 Different paths to knowledge
5.2.6 Journalistic knowledge (continued)

The role of science journalism

One must distinguish science journalism from science communication. Science communication includes the varied strategies aimed at promoting science to the public. Its purpose is to educate, increase awareness and build support for science. Science communication uses public relations, publicity campaigns, marketing tools, flyers, books, festivals, and science museums.

A science journalist, on the other hand, wants to give science back to citizens and help them benefit from science. Sure, most science journalists are closet admirers of science, but they, above all, cultivate the **art of doubting**, to make sure the public does not fall victim to bad, false or fraudulent science. French philosopher Gaston Bachelard said science journalists have one foot in the world where ideas live and the other in the world where we live.

Like the art or literary critic, the science journalist is a science critic. Being a **critic means asking questions** and **examining, selecting, describing, verifying, and explaining scientific facts** in order to find what is missing and to comment on the findings. He or she **analyses the science from different perspectives** – economic, sociological, political, ethical, and legal. In the end, the science journalist **can question the relevance, importance, and usefulness of the science**.

Above all, the science journalist relates scientific results to the needs and preoccupations of the citizens.

A science journalist must justify his or her job by making it possible for citizens to understand and make some use of science for their day-to-day benefit. This calls for more than simply translating science into common words with wonderful and striking analogies, metaphors and animated graphics. As a critic of science, the modern science journalist must explain how scientific truth is constructed. Thanks to good science journalism, everyone could then find out which **scientists to believe**, which not to believe; when to believe in science and when to withhold belief.

The competent science journalist will communicate the true state of science, where it is moving forward, sideways, backward or stuck.

Science journalism is no minnow in the journalistic world. It calls for lots of talent, openness, creativity, imagination, fascination with reality, ambition, and ... humility.

5.3 Limits to science
5.3.1 Introduction

The 20th century saw the triumph of science – culminating with man's footprint on the moon – as much its ability to enable humanity to self-destruct.

During the early part of that century, the eugenics movement sought to improve human beings through selective breeding, justifying the sterilisation of mentally disabled people. During World War II, atomic bombs – frightening offshoots of the genius of Einstein – fell on Hiroshima and Nagasaki, Japan. Today, the power of informatics and the internet threatens private life, whilst we are on the threshold of making our planet uninhabitable.

Yes, there is a dark and worrisome side to science.

Philosophers have tried to corner the true nature of science. At the end of the 20th century, antagonistic points of view on science led to the so-called "science wars." Luckily, the victims were a few academics with bruised credibility and prestige.

Oversimplified, the wars pitted mostly natural science researchers against a group of sociologists, historians, philosophers and feminists who were supposedly speaking for the left and describing science as a tool of repression, brutal capitalism, and warmongering machismo. Not interested in joining those scientists, but rather in exposing the excesses and nefarious uses of science, these intellectuals did their best to take science down from its pedestal, where it was placed as an unrivalled method to find the truth.

They turned the first part of this lesson upside down. For them, science is no true description of reality. Science is only one more religion, with its rituals, beliefs, dogma, competing sects and priesthoods. They took upon themselves to "deconstruct" the scientific temple and expose the true nature of scientific knowledge – reduced to the status of common knowledge – and to demystify the real practices of the scientists.

The following paragraphs will attempt to introduce in a few words the thinking of some key contemporary philosophers of science and protagonists in the science wars.

5.3 Limits to science
5.3.2 Thomas Kuhn (1922-1996)

Notwithstanding the relevance and efficiency of Karl Popper's concept of falsification (to be described in Section 5.3.3 [http://www.wfsj.org/course/en/L5/L5P19.html]), the most well known of the contemporary philosophers of science is Thomas Kuhn, author of The Structure of Scientific Revolutions, published in 1962 and still enjoying great popularity.

Kuhn said that the search for objective truth is not the real goal of science, but that **science is essentially a method of solving problems operating within a contemporary system of beliefs**. That system of beliefs and values manifests itself through a series of experimental procedures that produce results, which, in turn, reinforce the original system of beliefs and values. Kuhn calls such systems **paradigms**. Scientists, normally, spend most of their time doing **normal science** i.e. they work within a specific paradigm.

But, sometimes, the likes of Nicolaus Copernicus, Isaac Newton, Charles Darwin and Albert Einstein come up with new belief systems that trigger **scientific revolutions**. Respectively, their systems reshaped the universe such that its centre is occupied by the Sun and not the Earth; brought celestial mechanics under the same laws obeyed by terrestrial mechanics; moved from a world created by God to a world without purpose and never finished; and switched from a physics with an absolute and uniform flow of time to a new physics where the flow of time is elastic and varies according to the relative speeds of the experimenter and the observed.

Kuhn argued **new paradigms take over not because of their scientific merit, but because their adversaries eventually die**: the Einsteinians' general relativity becomes accepted as a true description of nature following the thinning of the ranks of Newtonians.

5.3 Limits to science
5.3.3 Karl Popper (1902-1994)

Karl Popper still provides the most incisive and efficient definition of science: Science is the knowledge that can be proved false – in his jargon, **science is what is falsifiable**.

According to Popper, science is a continuous exercise in refutation. **Each experiment and observation aims at contradicting the accepted theory**. Science would be nothing more than those theories saved from the falsification efforts of scientists. Popper puts systematic doubt as the foundation of the scientific approach. Scientists are driven by an ambition to discover and publish the observations that will contradict currently accepted theory – what Thomas Kuhn (the philosopher from section 5.3.2 [http://www.wfsj.org/course/en/L5/L5P18.html]), calls the "paradigm du jour" or "paradigm of the day."

In practice, most scientists most of the time are happy to repeat experiments and confirm previous results. Nevertheless, they also dream of finding the fault that could lead to new theory. The thousands of scientists impatiently waiting for the first runs of CERN's Large Hadron Collider in Geneva, were probably more interested in finding a "new physics" – opening new avenues – as in using the collider to confirm the existence of the famous Higgs boson, an elementary particle predicted by the Standard Model of Physics.

5.3 Limits to science
5.3.4 Induction and deduction

Induction, the most powerful and weakest link in science

During the first part of Lesson 5, we discovered that scientific laws and theories are "**generalisations**." For example, a copper bar increases in volume when heated; so does a steel bar, and an aluminum bar. All three are metals. The scientific method leads to the generalisation that the volume of metals increases when they are heated.

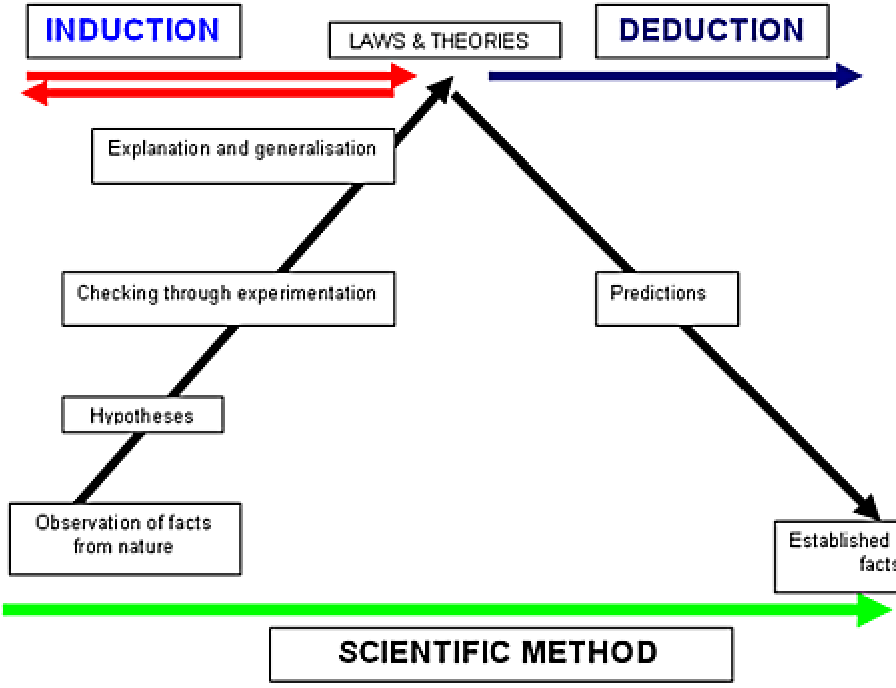
Generalisation – or to use the technical term, **induction** – consists of proposing a scientific law like "all metals when heated increase their volume," based on a series of observations where particular metals increase in volume when heated to different temperatures and under different settings.

Induction's weakness originates from the fact that any law based on it is **at the mercy of one single exception**. Scientific laws cannot call on the power of logic and deduction.

In **deduction**, "heated metals expand" is taken as a general truth, as is the statement "copper is a metal." Then, using the power of logic, it is a simple deduction that the volume of a piece of copper will expand if heated.

Since scientists can never be absolutely sure they have tested all metals, induction very naturally opens the door to **falsification**. Karl Popper's genius was to make this vulnerability the essence of science.

5.3 Limits to science
5.3.5 Scientific Method



This diagram is lifted from What is this thing called Science? by Alan Chalmers, University of Queensland Press, Open University press, Hackett, 1999.

It shows how scientists construct theories and laws using **induction**, and then deduct new facts and predictions based on these laws and theories.

5.3 Limits to science
5.3.6 Cultural relativism and science

Sociological constructivists hold that science is a pure product of society. They conclude that society determines to a large extent the beliefs of scientists: a scientist can call on her publications and studies; it is her sociocultural milieu that determines her belief in a certain scientific theory. The concept of science as a construction of each particular society at a particular time blends well with the philosophy of **cultural relativism**, which holds that each society has its truth, and each one is as valid as the other.

We witnessed a Dean of the Faculty of Sciences of the University of Yaoundé (Cameroon) open a workshop stating: "Us Africans, we need to invent our model of the atom." Others believe that the relatively small share of the scientific effort dedicated to solving the problems of the developing world is an intrinsic feature of a science dominated by the West. Some feminists have reasoned that a science with a larger share of women scientists would be more benevolent towards the environment.

Hossein Nasr, a famous Islamic scholar now teaching at Harvard, says that science as it exists presently is the product of a Western world committed to put nature at its service through "torture" if needed. He says an Islamic science would be different because nature is sacred in Islam. In India, some hope to create a different science based on Hindu concepts of space, time, logic and nature.

If science is a sociocultural by-product, could it be misused by different groups to promote their own interests, at the expense of other cultures, the environment and peace?

5.4 How is science constructed in real life
5.4.1 Science: it is what's in scientific journals

If you ask a scientific researcher what she does, she might answer: "I write papers for science journals." **It could then be said that science is what's in science journals**.

The validity of this definition rests on the fact that publishing is vital for any scientist – they must publish or perish. A scientist who does not publish has no status, no grants, and probably will soon be without a job. After a scientist has graduated from university, his or her career depends on a continuous stream of papers published, and particularly, on the number of these papers that are picked in the major science journals – those with the highest **citation index** and **impact** factor.

Scientific papers published in the best science journals undergo two tests. First, the publication's editors evaluate the overall quality but also the importance of the article. Then, they send copies of the article to several acknowledged experts in the same field known as "peers"; this is why these articles and journals are called "peer-reviewed."

All serious science journals have articles peer-reviewed before publishing.

Peer review is the process by which manuscripts submitted to scientific journals are evaluated by appropriately qualified experts (usually anonymous to the authors), to determine if the manuscripts are suitable for publication. These experts look particularly at the relationship between the methodology and the conclusions.

A **citation index** is an article database that indicates how many times the work of one author has been referred to, or cited, by other authors, and where. That is an indication of its importance.

The **impact factor** is a measure of the frequency with which the "average article" in a journal has been cited in a particular year or period; it is a ratio calculated by dividing the number of current year citations to the number of items published in that journal during the previous two years. It aims at eliminating some of the bias that favours large journals. Impact factors for several science journals can be checked at:
[http://www.sciencegateway.org/rank/index.html] This website is a mine of information on the scientific production of scientists, universities and countries, as well as http://sciencewatch.com/

5.4 How is science constructed in real life
5.4.2 The limits of peer review

Essentially, passing peer review says that other specialists in the same area of research think that the content of the reviewed paper is compatible with what is generally accepted in the field.

In fact, the real test for veracity will only happen once other scientists will have obtained the same results using the same methodology. **The truthfulness of peer-reviewed articles is only temporary**; as long as other experiments have not confirmed the stated conclusions, it is recommended to remain cautious about them.

EXAMPLE
The workings of the scientific method and the limited truthfulness of a peer-reviewed article are nicely illustrated in this video about whether or not a virus causes chronic fatigue syndrome. [http://www.newsy.com/videos/chronic-fatigue-syndrome-setback]

Do science journalists have unrealistic trust in peer-reviewed journals?

Certainly, peer review is not foolproof, not unfalsifiable. The most recent spectacular failure of peer review is the article by South Korean researcher Hwang Woo-suk who pretended to be the first to successfully clone a human embryo and produce stem cells from it. Science, the journal published by the American Association for the Advancement of Science, made sure that the issue carrying the article would coincide with its 2004 annual meeting, in Washington. There was enormous publicity for AAAS and Science with this publication. Damage to their reputation was even greater when it was found to be a fraud [http://www.sciencemag.org/sciext/hwang2005/] .

John Rennie, former editor-in-chief of Scientific American has four caveats about peer-reviewed journals, saying they are susceptible to:

- **Possibility of a mistake**: The content of a peer-reviewed paper is confirmed only once other scientists have reproduced the same results using the same methodology.
- **Fraud**: It is nearly impossible for reviewers to unmask deliberate fraud; the whole scientific publishing activity rests on the scientists' good faith. But science journalists are more complacent with science journals as sources than economics journalists are with financial reports.
- **Bias and dishonesty**: The authors have made a deal with sympathetic editors and publishers.
- **Political pressure**: For example, when the U.S. government tells scientific journals not to publish articles from Iran, Libya or Sudan.

But, even with these reservations, Rennie concludes that the rare occasions when peer-reviewed science journals fail should not deter science journalists from making the journals their privileged sources of information. (In Lesson Two of this online course you can also find a checklist of questions to ask to help you judge the validity of a scientist's claims [http://www.wfsj.org/course/en/L2/L2P10.html].)

5.4 How is science constructed in real life
5.4.3 Scientific truth by consensus

Today, science journalists report on issues that concern all of humanity.

Governments all over the world have to deal with threats toward the climate, water resources, energy reserves, private life and health. Decision makers and politicians face vital choices with major potential impacts on jobs, health, wealth, and even lifestyles of populations.

At the same time, it is nearly impossible to find out the exact status of the planet's resources of water, food, oil, gas, forests and arable land, and even more difficult to know for sure the exact short-, medium-, and long-term trends regarding these resources, the climate and potential technological fixes.

Facing these unprecedented global challenges, experts and governments have put in place some mechanisms to assess problems and, sometimes, make recommendations. These approaches bring together the best experts in the field, and provide them with support to meet, research and document issues and publish independently their conclusions and recommendations.

Such mechanisms can vary from a small committee asked to perform a state-of- the-art review on diet, to a committee of **national science academies**, to a special commission tasked with finding out why a bridge has collapsed, to a worldwide team of thousands of experts like the **Intergovernmental Panel on Climate Change (IPCC)**, which won the 2007 Nobel Peace Prize.

The IPPC mobilises thousands of scientists. They receive no salary and most work anonymously. They agree to read and make sense of extremely complex data, write review papers synthesising specialised articles, travel to meetings and then reach consensus on data interpretation, conclusions and recommendations. On top, the IPCC scientists had to have governments approve each one of their reports. It was gruelling work, but the participating scientists had the opportunity to check their research and mingle with the best in the world.

5.4 How is science constructed in real life
5.4.4 Resources

IPPC website: [http://www.ipcc.ch/]

Websites of some African and Arab science academies:

Egypt: [http://www.asrt.sci.eg/]
Jordan: [http://www.rss.gov.jo/]
Kenya: [http://www.knascience.org/]
Palestine: [http://palestineacademy.org/main/index.php]
Senegal: [http://www.asts.sn/]
South Africa: [http://www.assaf.co.za/]
Uganda : [http://www.uncst.go.ug]

Initiative for African science academies:
[http://www.nationalacademies.org/asadi/]

Overview of the philosophy and philosophers of science:
[http://en.wikipedia.org/wiki/Philosophy_of_science]

5.5 Self-teaching questions (1-2)

QUESTION 1:

Provide short answers to the following questions:

a) What does it mean to "know" an object?
b) Name a few of the great religions of the world.
c) Does day-to-day knowledge question itself and does it think it is immutable?
d) Do scientists use day-to-day knowledge?
e) How do we acquire common knowledge?
f) What is an "epistemological break"?
g) Where does in-depth or systematic knowledge begin?
h) What distinguishes systematic knowledge?
i) Can anybody truly understand a piece of art?
j) What kind of deeper knowledge provides science?
k) What are the characteristics of experimental science?
l) List a few approaches to knowledge.
m) What are the key steps of the experimental method?
n) Is science a kind of religion?
o) What criteria must a journalistic fact meet?
p) Give some representations of what science journalism is.
q) What is the role of the science journalist?
r) How do you evaluate the credibility of a scientist?
s) Do you evaluate the importance and influence of a scientist?
t) What four possibilities could cause you to have reservations about the quality of articles peer-reviewed journals?
u) What are the pros and cons for a scientist in participating in a scientific committee or commission?

QUESTION 2:

Consider the following and provide short answers:

a) Would you say that there are many different ways to "know"?
b) Do different populations have their own types of knowledge?
c) In your culture, what does to "know" mean?
d) Can you list some beliefs of your community?
e) Is astrology a belief or a science?
f) Give an example of a piece of common knowledge.
g) If I say: "the sun rises every morning and sets every evening", which repertoire of knowledge do I tap?
h) Who taught you that the sun rises and sets?
i) Can you remember some of the knowledge that you acquired in the company of other children and friends?
j) Does a physicist, a painter, or a sculptor have something in common?
k) Is it feasible to increase its understanding of some phenomena by going deeper than superficial impressions?
l) Can you describe the difference between reason and emotion?
m) Are there similarities between a mathematical equation and a poem?
n) Are there differences between a mathematical equation and a poem?
o) Is there any tradition in systematic knowledge?
p) Someone says: "Within the same day, I saw 36,000 sunsets," while another says that "the sun never sets." Which sentence is said by a poet and which is from a scientist?
q) What kind of people base their knowledge on aesthetics?
r) Which person uses true knowledge that can be demonstrated?
s) Which sentence is neutral, objective and universally true?
t) Why do we say that scientific knowledge is its own critique and is rational?
u) In your country, do scientists also think that they are artists?
v) What is the experimental method?
w) What is the use of experimental laboratories?
x) Has a scientist from your own country ever explained his or her methods to you?
y) What similarities exist between journalism and science?
z) Are there differences?
aa) Do you agree that the science journalist is a critic of science?

bb) What information do you have on scientific research in your country: its institutions, its laboratories and research facilities, its scientists and their achievements, and on the science and technology policy?

cc) Give three reasons that make science a threat to humanity and three reasons that would make science its saviour.

dd) If the media contribute towards constructing cultures, would journalist contribute? Are there differences between science journalism as practiced in Africa, Asia, in the Arab World, in the Western World? What are these differences, if there are any?

ee) Find out how many scientific articles are published by scientists from your country.

ff) Name some scientific journals published in your country, some peer-reviewed some not.

gg) Do you agree with John Rennie?

hh) Give an example of scientific fraud in your country.

ii) Name one scientific committee in your country.

jj) Give an example of some scientific recommendations that were either accepted or rejected, in your region or country.

kk) Does your country have a science academy?

ll) Do scientific committees and science academies speak the truth?

5.6 Answers to self-teaching questions (1-2)

QUESTION 1:

The questions will be listed in bold, followed by the answers in normal text.

Answers:

a) **What does it mean to "know" an object?**
To "know" and object means being able to describe all its visible and invisible characteristics in relation with the other objects in its environment.

b) **Name a few of the great religions of the world.**
Islam, Christianity, Judaism, Buddhism, and Hinduism.

c) **Does day-to-day knowledge question itself and does it think it is immutable?**
Within common knowledge, accumulated statements cannot change and remain the same forever.

d) **Do scientists use day-to-day knowledge?**
Scientists begin with common knowledge in their daily lives. Eventually, they break from its spell through their work.

e) **How do we acquire common knowledge?**
Common knowledge is built and transmitted by our families, relatives, close friends, neighbours, partners, tribe and community.

f) **What is an "epistemological break"?**
Bachelard coined "epistemological break" from the word epistemology, which is the study of knowledge. This course is a course in epistemology.

g) **Where does in-depth or systematic knowledge begin?**
Systematic knowledge begins as soon as one decides to stop being satisfied with the sole immediate information of our senses and stops trusting them. Then we have to dig a bit deeper. Then we become addicted to digging a bit deeper and start looking at things in a different way.

h) **What distinguishes systematic knowledge?**
Systematic knowledge seeks to look at things in a different light then the one that tradition provides. It launches us on a journey to create, imagine and discover the unknown. It makes us reject monotony and stop relying on tradition. It questions everything.

i) **Can anybody truly understand a piece of art?**
True art work can only be understood by someone who knows about art style, types, shapes, symbolism, production sites and history.

j) **What kind of deeper knowledge provides science?**
Deeper scientific knowledge relates to the truth that conforms to nature.

k) **What are the characteristics of experimental science?**
Experimental science is based on facts. It is fact-checking, objective, impersonal, universal and rational.

l) **List a few approaches to knowledge.**
The search for truth has been sometimes answered by religion, argument of authority, mysticism or common sense (common knowledge).

m) **What are the key steps of the experimental method?**
Modern science follows these steps: observation, experimentation, explanation, generalisation and prediction.

n) **Is science a kind of religion?**
Though it may look all powerful and seems to know no boundaries, science is no religion. Big and costly infrastructure may make science more present in some groups or populations but scientists themselves are from no particular race, sex, age, religion, skin colour or income bracket.

o) **What criteria must a journalistic fact meet?**
A journalistic fact must be true, real, connected to current events, new, significant and interesting.

p) **What is science communication?**
Science communication is seen as a means of disseminating science and its concepts by translating what scientists say into a language that the lay public can understand. It has also been seen as a means of raising scientific literacy of the public and creating a positive attitude towards science.

q) **What is the role of the science journalist?**
The modern science journalist is a science critic. Her role is to explain how scientific truth is produced in a way that would make it possible for citizens to find out whom to believe or not, when to believe scientist and when not to believe them. The competent science journalist will communicate the true state of science, where it is moving forward, sideways or backward or stuck.

r) **How do you evaluate the credibility of a scientist?**
Ask for copies of his or her articles and check if they have been published in peer-reviewed journals.

s) **How do you evaluate the importance and influence of a scientist?**
Find out from a citation index how many times his or her articles have been cited, and the impact factor of the journals in which the articles have been published.

t) **What four possibilities could cause you to have reservations about the quality of articles peer-reviewed journals?**
1) The possibility of mistakes, since they deal with only temporary truth.
2) The possibility of fraud, for example, with doctored photos.
3) The possibility of bias and dishonesty.
4) Political pressure stopping a journal from using only scientific criteria to decide in favour or against a specific paper.

u) **What are the pros and cons for a scientist in participating in a scientific committee or commission?**
Cons: workload, lots to read and synthesize, meagre recognition, need to reach consensus with inevitable tensions and conflicts, travel and often no financial reward; Pros: opportunity to find out about the most recent and most credible research, travel, meetings with the best experts in the field, and possibility to validate one's own research.

QUESTION 2:

A wide variety of answers are possible.

5.7 Assignments (1-5)

ASSIGNMENT 1:
Find out what the scientists in your country think of local science journalists.

ASSIGNMENT 2:
Chose your preferred philosopher of science amongst Kuhn and Popper and say why.

ASSIGNMENT 3:
In one page, explain if science is the product of a particular culture or a universal knowledge.

ASSIGNMENT 4:
Interview a scientist that had articles accepted (or turned down) by peer-reviewed journals. Ask why the article has been accepted or rejected; if published how long it took; and what has been the impact on his or her career.

ASSIGNMENT 5:
Compare a peer-reviewed and a non peer-reviewed journal. What are the differences?