The Reform Project

Progressive, enlightened voices from the Arab Muslim world

Towards a

Model Curriculum

For the reform of the educational syllabus

in the teaching of the humanities

[A] Courses

A2: The Methodology of Science

(Samples)

COURSE A2 - THE METHODOLOGY OF SCIENCE

> The duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads and, applying his mind to the core and margins of its content, attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency.
>
> Ibn al-Haytham (965-1040) [1]

As the knowledge-driven nature of modern societies becomes more apparent, it is important for students to gain a better understanding of the nature and construction of knowledge, and apply this understanding to the different areas of knowledge they may be engaged in. A curriculum for a modern knowledge society will therefore need to develop in students, via the process of inquiry, the skills and attributes that will enable them to understand how knowledge is constructed and how to critically evaluate that knowledge.

Educational theorists, from the earliest examples of the genre,[2] agree that developing the skills of critical evaluation is crucial to the development of self-confidence to participate and innovate, and they recognize that a curriculum aimed at building thinking skills is fundamental not only to the individual learner, but to the building and maintaining of a stable society, economy and political system.

This self-confidence to innovate and act independently is a particular problem in the Middle East, where the practice of education by rote-learning has yet to be substantially challenged, [3] and where the teaching methods focus on imparting content rather than techniques of thinking. "The notion", observes Khaled Fahmy, professor of history at the American University in Cairo,

> is that there is a finite amount of knowledge, so there is a standard text book that has to be taught and students have to acquire that information ... The professor delivers a lecture which is a repetition of the set text book for the course which he has written and the students are examined on this information.[4]

Various theories have been put forward as to why this static method persists as the default educational model but early learning patterns conditioned by cultural factors appear to emphasise uniformity, a general discouragement of 'thinking outside the box' and an anxiety of appearing or being different.

There is therefore a pressing need to establish for Muslim students not only the requirement to understand and practice science 'properly and in a manner that is faithful to its methodology and tradition' but also its propriety as something 'critical to the creation of a productive scientific environment and a scientific culture in the Muslim World'.[5]

---

[1] Al-Ḥasan Ibn al-Haytham, الشكوك على بطلميوس'(*Doubts Concerning Ptolemy')*, eds. A. I Sabra, and N. al-Shihabi, Dār al-Kutub, 1971, pp.3-4. فطالب الحق ليس هو الناظر في كتب المتقدمين، المسترسل مع طبعه في حسن الظن بهم، بل طالب الحق هو المتهم لظنه فيهم، المتوقف فيما يفهمه عنهم، المتبع الحجه والبرهان لاقول القائل الذي هو إنسان، المخصوص في جبلته بضروب الخلل والنقصان. والوجب على الناظر في كتب العلوم، اذا كان غرضه معرفة الحقائق، أن يجعل نفسه خصما لكل ماينظر فيه، ويجيل فكره في متنه وجميع حواشيه، ويخصمه من جميع جهاته ونواحيه، ويتعم أيضا نفسه عند خصامه فلا يتحامل عليه ولايتسمح فيه.

[2] See, for instance, the pioneering work on this by John Dewey, *How we think*, New York 1910. John Dewy remains the most influential thinker on education in the twentieth century.

[3] It may be more broadly represented across the Muslim world, and subject to the paradigm of religious faith where the highest achievement of learning is popularly considered to be the memorisation of scripture. C.f. the interesting example given by an Indian chemist on a visit to Pakistan: "I was walking near my house one Sunday afternoon when I heard a male voice raised in a monotonous chart, I suppose that I was listening to some mantras, and asked my companion if he could identify them… But my companion stated that the language of the chant was English and the subject organic chemistry. We returned, and I found that he was right. The subject of the chant was the preparation of aliphatic amines, with special reference to various precautions." Cited in Pervez Hoodbhoy, *Op. cit.*, p.38.

[4] Heba Saleh, 'State education: Bias towards rote learning stifles critical thinking', *Financial Times*, October 20th 2013.

[5] The 2016 *Istanbul declaration on Islam and Science.* published with the *Islam and Science Report* by the Muslim Science Task Force, March 14, 2016. Dr. Munā Abū al-Faḍl has also argued that "it is time that we grasp the reins of our situation and resolve to

Module A2.1 - PRELIMINARIES

As a preliminary to the exploration of the scientific method the educator will need to instil a number of preparatory disciplines in the student that will counter the legacy of faulty educational methods.

A2.1.1 – Developing the scientific attitude

The Route to Knowledge, as we have seen from its development over history, demonstrates that science cannot be considered a body of knowledge so much as *a way of thinking*. The evident success of this way of thinking in the production of meaningful advances in understanding the physical environment is due to the fact that it has a built-in error-correcting mechanism.

The pedagogic model will need to place emphasis on encouraging dissent and challenging non-dissent. Since this goes to the core of the individual's cultural conditioning, the educational reform will not limit itself to teaching how to research and find information, or how to analyse and critique the validity of the information and its arguments, but will extend to encouraging the students to examine their own thinking processes for flaws, culture and group-specific influences, and personal biases. These negative influences have to be countered by a conscious training to inculcate positive-leaning attitudes that are conducive to knowledge acquisition such as:

- open-mindedness (freedom from prejudice, partisanship and other such habits as close the mind)
- whole-heartedness (genuine enthusiasm)
- responsibility (a willingness to consider the consequences of a projected step and adopt these consequences when they follow reasonably from any position already taken).

The challenges of inculcating these attitudes in the Middle East, as we have seen, are particularly acute since the unresolved ambiguities of the relationship between science and religion in the region are presenting a set of obstacles that do not exist, to anything like the same degree, elsewhere. Given this cultural context the question of asking questions about results and processes of enquiry inevitably comes up against the problem of revisiting fundamentals of knowledge that are normally 'taken for granted'. Nevertheless, as the Jordanian molecular biologist Dr. Rana Dajani insists, the priority for a dynamic approach to learning must not be sidestepped:

> What we should strive for is to teach/instruct our students to develop a rational methodology of assessing the natural world around them and to think independently to come up with their own opinions, hypotheses and theories. If we succeed in that endeavor the rest of the controversies between science and religion will be resolved.[6]

As we have demonstrated, there is no inevitability of a clash so long as the focus is placed on epistemological techniques rather than metaphysical implications, if there are any.

---

adopt the scientific method so that we contribute our share in adding to the stock of the contemporary human sciences, taking all the while as starting point our own experience and cultural distinctiveness, in addition to our own initiatives in this effort towards resolving our practical problems." See Dr. M. Abu al-Faḍl, مفهوم الأمة وأزمة الفصام بين العلوم الإسلامية والإنسانية - الإحياء , Vol. 29, January 2009, p.88.

[6] Dr. Rana Dajani, 'Evolution and Islam – Is there a contradiction?', *Muslim Science*, August 9th, 2015.

A2.1.2 - Legitimising doubt, questioning and self-examination

In the face of a cultural framework that places a high premium on absolutism, the primary task for the educator is to establish, in the minds of the students, the propriety and legitimacy of *doubt, skepticism* and the *provisional nature of knowledge*. To students brought up in a scheme that emphasises a relationship of *'truth = certainty',* resistance to this may prove strong, but the task is to make students aware that the building of knowledge is an ongoing, non-linear process consisting of creating, building, demolishing and rebuilding ideas/thoughts. It is the open-endedness of discussion that is the crucial feature to establish.

Legitimising questioning

The educator will equally be required to outline the stages of certitude, how knowledge comes to be validated (and what this means) and granted its authority, with appropriate emphasis on the provisional nature of this authority. The processes of accumulation will focus on the role of *facts, argument, reasoning and logic* and the crucial function of questioning the sources of the knowledge and its authorship. In the classroom the student is to be encouraged to develop the habit of posing, and responding to, the following features of Socratic questioning:

- *Clarifying thinking and investigating the origin of this thinking*:

  ('Why do you say that?', 'Could you explain further?')

- *Challenging assumptions*:

  ('Is this always the case?', 'Why do you think that this assumption holds here?')

- *Using evidence as a basis for argument*:

  ('Why do you say that?', 'Is there reason to doubt this evidence?')

- *Adducing alternative viewpoints and perspectives*:

  ('What is the counter-argument?', 'Can/did anyone see this another way?')

- *Envisaging implications and consequences*:

  ('But if...happened, what else would result?', 'How does...affect...?')

- *Questioning the question*:

  ('Why do you think that I asked that question?', 'Why was that question important?')

Encouraging self-examination

Fundamental to this validation is the importance of applying the questioning process to the problem of *the subjective inquirer.* The student is to examine the issue of their own personal biases and limitations in a specific field of enquiry, along with the biases and limitations of others – and how these elements may affect the accumulation and construction of knowledge.

Related to this is the exploration of the possible *conflicts* between the different fields of knowledge, the fundamental differences in the way knowledge is constructed in these fields, and how these differences may result in different conclusions being drawn. Conspicuous arenas for this exploration will be the contexts of reasoning on the basis of scripture and the natural world, and the broader question of religious truth and scientific (empirical) truth, as it has unfolded over history.

Module A2.2 – BASIC METHODOLOGICAL PRINCIPLES

Although this is not the place to provide a detailed scientific methodology, which is a large field with many specialisms and one that is constantly evolving, the route to knowledge as illustrated in *Course [A1] The Historical Rise of the Scientific Method*. is emblematically represented by the accumulated development of certain disciplines and attitudes. Over the long history of human endeavours expended in understanding the workings of the natural world –endeavours which we have seen have been entirely cross-cultural – a number of techniques were developed and progressively refined to maximise efficiency and accuracy. As a summary of the route to knowledge section of the curriculum it would therefore be useful here to set out the basic features of the method that forms the conceptual starting point for the modern knowledge society.

In instilling into the student the mechanisms of this method – which by its nature is applicable to far broader fields of investigation than exclusively the exact sciences – the educator will need to focus on a number of preliminaries. These include, at the outset, improving precision in the employment of terms, maintaining clarity and conciseness in language, avoiding the use of 'loaded' language, understanding the exclusively positivist arena for the practice of scientific reasoning (recognizing only that which can be scientifically verified or which is capable of logical or mathematical proof) and defending objectivism over relativist currents of thought.

A2.2.1 - *Precision in vocabulary and definitions*

A number of terms present some ambiguities due to their being employed in common discourse in a way that differs from scientific usage:

Assumption More than a 'belief' or an 'opinion', an assumption is an element that is 'taken to be true without proof.' The role of the assumption in scientific investigation is not a negative one because assumptions fulfil the role of a provisional starting point. Nor is an assumption necessarily a guess, since they are often made based on some contextual knowledge and expertise;

Construct In scientific usage this denotes a non-testable statement (such as a folkloric tradition or a theological doctrine) to account for a set of observations. Scientific investigation does not make use of the construct;

Hypothesis A scientific hypothesis is a model of some kind which will describe or explain how something in the universe works. It guides the investigator in selecting what to observe and must be constructed in such a way as to be able to predict phenomena which can then be checked. Its goal is to expand knowledge; if this is going to work and develop real new knowledge, the hypothesis needs to meet a set of criteria called *Criteria of Adequacy*. They are:

- *Simplicity* – The hypothesis should require no more assumptions, factors or explanations than are absolutely necessary (this is the principle of 'Occam's Razor' mentioned earlier). A hypothesis with the fewest assumptions or factors offers the fewest opportunities to be wrong.
- *Conservatism* - The hypothesis must not be outlandish, but should fit into the broad realm of established knowledge. If a hypothesis is proposing to violate some well-established rule, it is not likely to be correct. "Extraordinary claims" as Carl Sagan famously argued "require extraordinary evidence".
- *Testability* - This simply means that there must be some means of testing the hypothesis. The test must have the possibility of refuting the hypothesis – falsifiability – showing that is wrong. A hypothesis that cannot be rigorously

tested cannot be considered a *scientific* hypothesis. Hypotheses can only be disproved, never proved. If a hypothesis withstands repeated trials by many independent researchers, then confidence grows in the hypothesis.

- *Scope* - The hypothesis should add to existing understanding, or at least extend or improve it. When a hypothesis has a 'larger scope' it means that it can predict more diverse phenomena than other hypotheses.
- *Fruitfulness* - A well constructed hypothesis will turn out to explain more things than it originally set out to explain. A hypothesis that makes unexpected and new predictions that turn out to be accurate is therefore 'fruitful'.

Theory The term is not the same as is employed in common discourse. The U.S. National Academy of Sciences defines the term 'theory' thus: "A well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses." While popular usage equates the word theory with 'hypothesis', a theory is actually much further along the road to certainty than a hypothesis since it represents a hypothesis, or group of related hypotheses, that have been *confirmed through repeated experimental tests.* Nor are theories easily discarded; new discoveries are first assumed to fit into the existing theoretical framework. It is only when, after repeated experimental tests, the new phenomenon cannot be accommodated that scientists seriously question the theory and attempt to modify it.

Fact In scientific parlance, a 'fact' is an observation that has been repeatedly confirmed and for all practical purposes is accepted as true, or confirmed to such a degree that it would be perverse to withhold provisional assent.

A2.2.2 - The elimination of bias and the importance of objectivism

Before proceeding further, the educator will need to establish in the students a consensus that:

- There is an objective reality which is the same for everyone;
- There exist unchanging laws by which the Universe works, and these laws can be discovered (not invented) through experimentation.

These objectivist statements constitute the fundamentals of scientific endeavour – that reality is an *absolute*, and that facts are facts, regardless of any one observer's preferences or cultural conventions or prerogatives.[7] It assumes that there is a world independent of our minds to which our thinking must correspond if our ideas are to be true and therefore of practical use. Objectivism holds that *reason*—the faculty that operates by way of observation and logic—is man's most reliable route to knowledge. Man gains this knowledge by perceiving reality with his senses, forming concepts and principles on the basis of what he perceives, checking his ideas for consistency with reality, and correcting any contradictions he discovers in his thinking. Thus, Objectivism rejects all claims to the idea that knowledge can be acquired by non-sensory, non-rational means. If the issue of the problem of ultimate proof were to be raised, the answer is *si monumentum requiris, circumspice* ('If you seek a monument, look around you'). The track record of scientific achievement, and its ability to accurately predict future phenomena, makes its own case.

[7] On the three important categories of *ontology* (what objects exist in the world? What statement about these objects are true?), *epistemology* (how can human beings obtain knowledge of truths about the world? How can they assess the reliability of that knowledge?) and *sociology of knowledge* (to what extent of the truth known or knowable by humans in any given society influenced or determined by social, economic, political, cultural and ideological factors?) see A. Sokal, and J. Bricmont, J. *Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science,* Picador, New York, 1998, p.272.

A2.2.3 - The avoidance of relativism

The alternative to scientific objectivism is relativism. Here the educator will need to demonstrate the shortcomings of a relativistic approach to knowledge and the scientific enterprise that attempts to deconstruct the premises upon which the progressive accumulation of knowledge is based.

Relativism is frequently associated with post-structuralist thinking and, in its more popularised understanding, assumes a solipsistic view that each person has a reality unto themselves, and that all perceptions and points of view have equal validity. Under this scheme each observer has their own *distinct* set of experiences, which go to make up a very *different* body of evidence on which to base knowledge. One's beliefs, even scientific beliefs, are thus subject to, and dependent upon, personal experience or cultural background.[8] If one's own beliefs and knowledge might change from time to time, the argument runs, it is reasonable to suppose that others' might as well.

This ongoing debate, known as the science wars, is pitching the above claims that scientific knowledge is not representative of any form of fundamental truth, against scientist realists who maintain that the evidence shows that scientific knowledge does reveal real and fundamental truths about reality. These also argue that there are several objections to the post-structuralist starting-point.

Firstly, it is a logical, self-refuting contradiction. To say that everything is relative, is to say that no universal generalizations are true. But the statement "no universal generalizations are true" is itself a universal generalization. So this statement must be false – which means that under this same logic there are indeed universal generalisations that are true.[9]

Secondly, there is the negative effect that relativism has on the self-correcting mechanism of investigation. It makes it impossible to believe that one is in error, for if there is no truth beyond an individual's belief that something is true, then an individual cannot hold their own beliefs to be false or mistaken. This means that the views of the proponent will not be revised, not even in the face of contradictory experience. Yet science is founded upon the willingness to *change views* based on the message of the evidence. It is precisely the mark of the unreasonable, of the unscientific, that they will not change their beliefs even in the face of evidence, that their 'knowledge' is constant and unchanging. In effect, relativism is a recognition that knowledge and truth are empirically delimited, and hence contingent and subject to change, not the uncritical acceptance of any proposition, no matter how poorly formed and supported. Relativizing truth to individuals effectively destroys the distinction between truth and belief in truth.

Thirdly, in framing itself as a criticism, it stifles the all-important critical spirit. Arguing for one's personal relative truth suggests that others do not have the right or grounds to criticize this truth – which constitutes another correcting mechanism of investigation. Scientific communication is an invitation to others to reproduce and /or disprove one's own hypotheses, using a consistent terminology and a commonly agreed arena and rules for debate. By the acceptance of a common communication-idiom of this sort, the critic is in turn enabled to measure his or her own individual experience to that of the proponent. Without that idiom it is a dialogue at cross-purposes. *Legitimate* differences in experience and perception lie precisely at those points were personal experiences and perceptions differ.

Fourthly, relativism generates an 'anything goes' antinomianism. The fact that each has a different perception of phenomena, does not free us from the discipline of basing our knowledge on experience and reasoning. That each of us has a slightly different basis for our knowledge or belief does not legitimize the employment of *no* basis for knowledge or belief.

---

[8] This has been termed 'cognitive relativism', the belief that there are no objective truths but only local beliefs, and has been satirised by Alan Sokal and Jean Bricmont *op.cit.*

[9] Charles Dougherty (*The strictures of scientific relativism*) put this view another way: "If his view is that all truths are relative to some perspective, we may validly counter that this is merely the relativists' perspective. If the relativists' rejoinder is that truth is relative not only from his perspective but from every conceivable perspective, he is well on his way to refuting himself by offering a non-relative claim."

Fifthly, it is unproductive. The concept of relativism can do little more than make one appreciate the diversity of perceptions and satisfy an urge to challenge or demystify a perceived (but not actual) 'arrogance' of the practitioners of positive science in their claims to a privileged knowledge of the world. By surrendering to a perception that 'everything is an unfathomable mystery' like this, it cannot produce knowledge that others can use. [10]

The quantum physics question

The focus of science upon knowledge that can be useful and a preliminary to new knowledge – as opposed to any number of unfathomable mysteries – means that the conundrums thrown up, for instance, by quantum physics (in particular the dual particle-like and wave-like behaviour and interactions of energy and matter, or the issue of whether an object under study is disturbed by the process of observation) have no bearing on the validity and efficiency of modern science at anything other than at the most minute sub-atomic scale. Contrary to the wishful thinking of those who would see modern science and its determinism as an evil that has been refuted by them, the revelations of quantum physics do not make the case for abandoning the accumulated experience of centuries in favour of a non-material approach to the physical environment. "While flights into metaphysics are all very well", argues Pervez Hoodbhoy,

> let us not forget that quantum physics stands on the solid bedrock of a million experiments. The scientific method remains intact in its integrity and power, and quantum physics remains very much a product of this method.[11]

In fact physicists are inclined to see the relationship as intimate, not antagonistic and to view classical, Newtonian, physics as simply the macroscopic domain of quantum mechanics.[12] The discoveries of quantum mechanics are thus an integral part of the scientific enterprise and not a deviation from it.

[10] S. Rayner, *Risk and Relativism in Science for Policy*. In: Johnson B.B., Covello V.T. (eds) *The Social and Cultural Construction of Risk. Technology, Risk, and Society* (An International Series in Risk Analysis), vol 3. Springer, Dordrecht.

[11] Pervez Hoodbhoy, *Islam and Science, Religious Orthodoxy and the Battle for Rationality*, Zed Books, 1991, p.18.

[12] Under what is termed the 'correspondence principle' the apparently odd behaviour of matter revealed by quantum mechanics and relativity theory become more apparent when dealing with particles of extremely small size or at velocities approaching the speed of light. But the laws of classical Newtonian physics remain accurate in predicting the behaviour of the vast majority of "large" objects or at velocities much smaller than the speed of light.

Module A2.3 – THE METHODOLOGY OF EFFECTIVE ARGUMENT

Once the culture and validity of doubt and questioning is fully inculcated in the student, the route to knowledge course can progress onto enabling the student to interact with knowledge and build on it to produce new knowledge. The educator will structure his course to demonstrate how the process of argumentation works and how the student will present the results of his or her argument in a rational, thorough and honest way.

A2.3.1 – Constructing questions, collecting data, formulating a thesis

For this the educator will need to establish some rules of thumb in constructing and defending an argument. These general rules will include, for example: setting out the purpose ('premises') of the thesis and the conclusion it intends to demonstrate, starting from premises that are reliable, and presenting ideas in a logical sequence. The educator will introduce a number of techniques that train the student to nuance his decisions according to a consistent methodology of evidence-gathering, evaluation and testing. These techniques will include how to construct meaningful and productive questions, how to test and challenge established authorities, how to order the investigation in a coherent sequence, the role of facts and the neutral accumulation of data, along with the application of reasoning and logic. In presenting the argumentation of the thesis, the educator will stress the following techniques and disciplines:

The use of examples: the importance of providing more than one corroborating example, and ensuring that the examples be properly representative and balanced by the conscientious use of counter-examples;

The use of analogy: the need to ensure that the analogy is valid by the use of *relevantly* similar examples;

The use of authority: sources should be informed and impartial, they should be cited and cross-checked. The student should be made aware that any personal attacks on the source that he/she comes across do not necessarily disqualify it;

Arguments on causes: explain how cause leads to effect and propose the most likely cause. The student should understand that correlated events may have a common cause but are not necessarily related, and that causes may be complex;

Thesis composition: *Preparation* – explore the arguments on all sides of the issue, question and defend each of these argument's premises, revise and rethink the arguments as they emerge;

Definition and structure – explain the question, make a definite claim or proposal, develop the argument fully, consider the objections that may occur, and consider possible alternatives to the interpretation;

Presentation – keep the introduction brief, keep to the outline, present the arguments one at a time, make sure to clarify each point. When featuring objections make sure to support it with their arguments, confine conclusions and claims to that which you are being shown in the presentation of the argument.

A2.3.2 – Falsifiability, predictive power and repeatability

The educator will outline to the students that the aim of the scientific method is to bring humans to an understanding of how the universe is, rather than how they wish to perceive it, and to construct an accurate, reliable, self-consistent, and non-arbitrary representation of it. To do this the method distinguishes itself from other modes of explanation by its requirement of systematic experimentation and independent validation. These are based upon the following infrastructures:

- *The propriety of doubt*, which has permitted the construction of a conceptual scheme and modus operandi in which doubt is constantly adduced as a validating mechanism. The fact that doubt is incorporated as a mechanism of an ongoing, open-ended hypothesis, rather than a feature to be expelled on reaching 'certainty', can be seen in the *predictions* and *experiments* categories listed earlier (unit *A2.2.1*);
- *The 'falsifiability' criterion* which declares as non-scientific any proposed explanation that will not present ways of checking it, so as to confirm it or reject it as incorrect. Any hypothesis that is presented should state the test conditions that could render it false. (Miracles, or a statement from scriptural authority, are thus not falsifiable since there needs to be at least a theoretical possibility that they can come into conflict with observation. For whatever truths they might hold, they are not part of science). Typical techniques for the falsifiability criterion include statistical analyses on probability, blind controls and randomization;
- *The repeatability of the test*. In a field where there is active experimentation and open communication among members of the scientific community, the self-correcting mechanism is assured: individual experiments or experimenters can be wrong, but the mistakes and biases of individuals or groups are the most likely to be cancelled out under this method, because experimental tests are repeated by different scientists who may have different biases.

A2.3.3 – The interpretation of data – the use of inductive and deductive reasoning

The aspiration to objective observation, the neutral accumulation of data and the checking of general perceptions against experience are the signal features of the scientific method. In demonstrating the workings of this process, the educator will establish a number of basic features of the methodology, such as the difference between:

- *Inductive reasoning* (from the specific to the general - using an observation to formulate a theory or idea. It involves drawing on many different facts, concepts, or opinions to come to a larger conclusion, and embraces trial and error experimentation);
- *Deductive reasoning* (from the general to the specific - the process of taking a known idea or theory and attempting to discover more information about why the known is what it is).

The educator will usefully supply observations on the relative productivity of these two methods. In so doing the educator can demonstrate how scientific methodology prioritises *inductive* reasoning, since it permits the application of a practically achievable sample of evidence not previously conditioned by the observer. On the other hand, *deductive* reasoning is employed mostly as a support (in the form of programmed testing of the results obtained by inductive reasoning). The evidence of the scientific record over history demonstrates the effectiveness of this prioritisation.

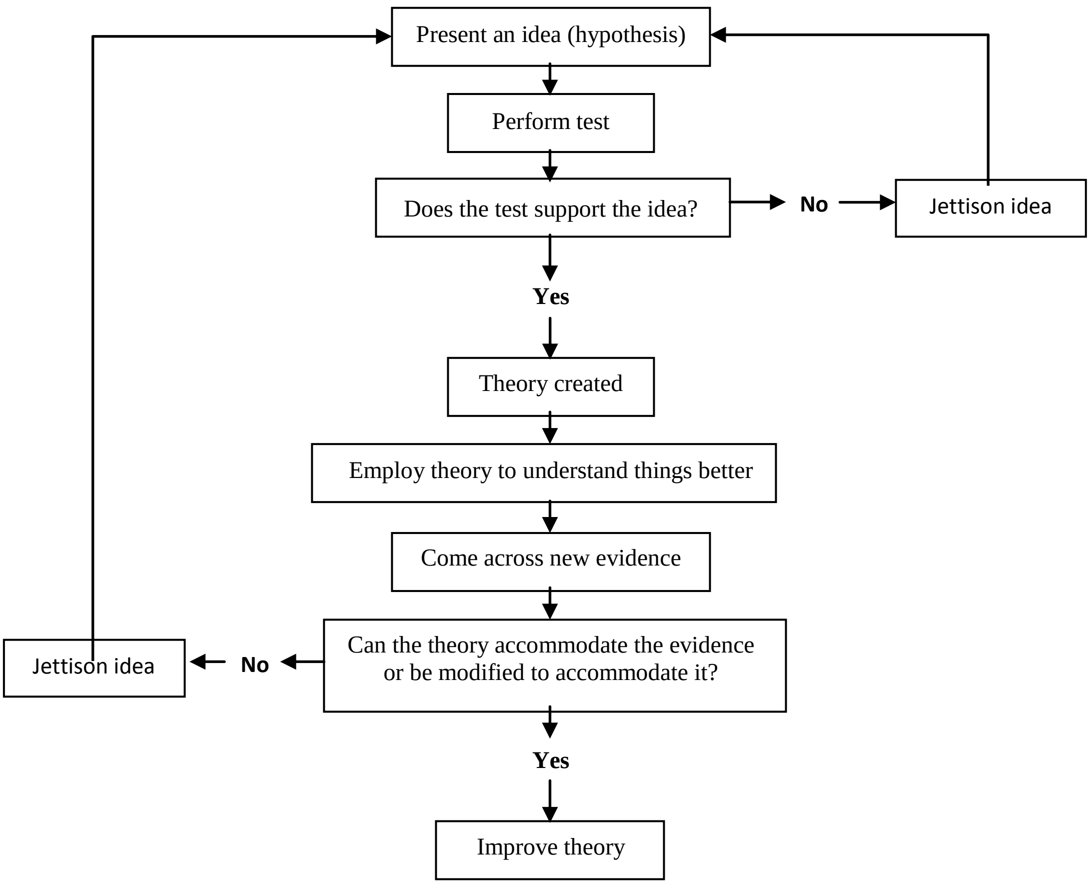
A2.3.4 – The structure and sequence of investigation

By way of summary the educator can illustrate the experimentation process as typically proceeding according to the following sequence:

1. Observe and describe a phenomenon to be explained

2. Formulate a hypothesis to explain the phenomenon. The hypothesis may take the form of a causal mechanism or a mathematical relation. The mechanism in each case should be plausible.
3. Design an experiment or observation to test the hypothesis
   a. The hypothesis should predict the existence of other phenomena, or predict quantitatively the results of new observations
   b. The construction of the experiment should include factors that, if observed, would contradict and invalidate the hypothesis
4. Carry out experiments to test the predictions of the hypothesis. Have these experiments carried out by several independent experimenters.
5. Analyse the results and compare them to the original hypothesis, applying the principle of parsimony (Occam's razor)[13]
6. If the experiment fails, return to stage 2.
7. If the hypothesis passes repeated tests, and similar results achieved by independent experimenters, the hypothesis can be validated.

The sequence of the scientific method may be illustrated by the following diagram:



[13] This principle underlies all scientific modelling and theory building. In any given model, Occam's razor helps us to "shave off" those concepts, variables or constructs that are not really needed to explain the phenomenon. By doing that, developing the model will become much easier, and there is less chance of introducing inconsistencies, ambiguities and redundancies.

Module A2.4 - ARGUMENTATION FALLACIES AND THE DETECTION OF PSEUDO-SCIENCE

A2.4.1 – Key indicators of weak scientific reasoning

Finally, the educator can inculcate awareness of key indicators of weak scientific reasoning, and those which indicate a weak, deceptive or instrumentalised hypothesis, such as the reliance upon selective or anecdotal evidence supportive only of the investigator, the absence of testing to the claims or confirmation bias (selectivity of evidence), the over-reliance on 'authorities' to make the case, arguments made *ad ignorantiam* (arguing that the claim is true simply because it has not been shown to be false), the over-reliance on confirmation rather than refutation, the employment of the false dilemma (reducing the complexity of the discussion to two alternatives), the use of unacceptably low samples, the use of circular arguments, the red herring distraction, unhelpful correlation assumptions and the danger of drawing conclusions that do not follow from the argumentation (the '*non sequitur*') and so on.

A2.4.2 – Key indicators of pseudo-science and deception

Finally, the educator can alert the student to more serious offences against scientific probity, particularly in the arena of disputatious argumentation. These include the use of deliberately obscurantist language or over-technical jargon, or the posing of complex loaded questions and definitions in order to deter criticism and attempts to evade peer review. The educator can warn of techniques undertaken by those with suspect motives, such as placing the burden of proof upon the skeptic rather than on the hypothesis itself, or the employment of loaded descriptions of others' argumentation (the so-called 'straw man' arguments), or the employment of *ad hominem* argumentation (attacking the character, motive or other attribute of the person critiquing his argument, rather than attacking the substance of the criticism itself). These and other dishonest techniques, which lay claim to science and the scientific method, actually constitute the antithesis of science. Such 'pseudoscience' ignores one or more of the steps of the scientific method, even if it makes generous use of the technical vocabulary of science. The following are typical markers of pseudo-science:

- A heavy reliance on testimonials by 'authorities' or anecdotal evidence ;
- The inclusion of built-in or *ad hoc* excuses for failure ;
- Hypotheses that are non-falsifiable, or where no serious attempt has been made to disprove them through testing;
- The lack of measurement or observation of the claims of the hypothesis;
- A testing regime that is based on very few samples, leading to a hasty conclusion that has not considered all of the variables;
- Unjustified polemics:
    a. Attacks made on existing explanations that do not offer anything new
    b. Attempts to disprove existing explanations on the basis of the *number* of attacks as opposed to their *cogency*
    c. Misrepresentation of the scientific work of others
- Observer bias, whereby the phenomena under investigation are interpreted in unobjective ways. This can be due, for example, to
    a. *wishful thinking* ("It can't be *n*, so it isn't")
    b. *confirmation bias* (the tendency to search for, interpret, favour, and recall information in a way that confirms the hypothesis while giving disproportionately less attention to information that contradicts it)
- The faulty adjudication of apparent evidence for the hypothesis, as a result (among other things) of:

a. *apophenia* (the tendency to perceive meaningful patterns within random data)
b. *correlation assumption* – in which two or more events occurring together are taken to have proved a cause-and-effect relationship. This may come about from the *cum hoc ergo propter hoc* ('with this, therefore because of this') fallacy or the *post hoc ergo propter hoc* ('after this, therefore because of this') fallacy. Such thinking makes unjustified connections between events which may happen together frequently without a causal connection, or which may be explained by a separate, additional causal factor in common.

- The hypothesis makes no progress, makes no useful predictions and generates no new knowledge.

Conclusion on the scientific method

Having established the conceptual background to knowledge acquisition, and its historical rise over centuries of human endeavour, the educator can demonstrate conclusively that far from some alien superstructure imposed over other cultures and heritages, what is now termed the 'scientific method' is an organic, culturally undifferentiated, collectively accumulated product of human experience.

Most importantly, the educator will demonstrate that despite the lack of 'certainty' that the scientific method yields, *its methodology does not lack authority*; it is simply that the user has to be contented with the *provisional* nature of that authority. If it does not provide the conviction that other approaches to knowledge claim to provide, and appears to be an impersonal exercise impervious to 'feeling', this is not the result of an antinomian, insensitive arrogance to cultural norms and sensibilities. Modern science simply attempts to be as intellectually responsible as possible, doing everything it can to exclude bias, and to conduct itself in openly scrutable ways. The philosopher Bertrand Russell summed up the common-sense position to adopt concerning the open-ended fluidity of scientific explanation:

> For my part, I have no doubt that, although progressive changes are to be expected in physics, the present doctrines are likely to be nearer to the truth than any rival doctrines now before the world. Science is at no moment quite right, but it is seldom quite wrong, and has, as a rule, a better chance of being right than the theories of the unscientific. It is, therefore, rational to accept it hypothetically.[14]

As the educator can easily demonstrate, there is in fact an essential humbleness about the modern scientist, something that is forced upon him by the constant scrutiny of his peers and the consequent requirement to continuously review his hypothesis in the face of new evidence that might expand, or contract, its validity. The honour paid to a scientist is forever a temporary affair since, as Thomas Aquinas warned over seven centuries ago: *locus ab auctoritate est infirmissimus* – "an argument appealing to authority is the weakest argument there is".[15]

…

By thus illustrating the advantages of the scientific method, and the pitfalls of failing to adhere to its standards, the educator will be playing a vital role in vindicating the indigenisation of modern systems of knowledge acquisition into the heritage of the student in the Middle East. Most importantly, the educator will be introducing to the student a new dimension to the understanding of what constitutes an authentic and authoritative route to knowledge.

[14] Bertrand Russell, *My Philosophical Development*, Routledge, London 1995, p.13.

[15] Thomas Aquinas, *Summa Theologiae*, Part 1, Question 1, Article 8, Objection 2.

Further reading

Aquinas, Thomas. *Summa Theologiae*, Part 1, Question 1, Article 8, Objection 2.

Bailey, C. *The Greek Atomists and Epicurus, A Study*, Russell & Russell, New York, 1926.

Curd, P and McKirahan, R. *A Presocratics Reader: Selected Fragments and Testimonia*, 2nd ed. Hackett, Indianapois, 2011.

Dajani, R. ‘Evolution and Islam – Is there a contradiction?’, *Muslim Science*, August 9th, 2015.

Dewey, J. *How we think*, New York 1910.

Dougherty, C. *The strictures of scientific relativism*, Transactions of the Nebraska Academy of Sciences and Affiliated Societies, 291 (1980).

Gauch, Hugh. *Scientific Method in Practice*, Cambridge University Press, 2003.

Greenblatt, Stephen. *The Swerve, How the World Became Modern*, W.W. Norton, New York, 2011.

Hoodbhoy, P. *Islam and Science, Religious Orthodoxy and the Battle for Rationality*, Zed Books, 1991.

Kelley, D. *The Art of Reasoning*, (W. W. Norton).

Moore, B.N and Parker, R. *Critical Thinking*, by (Mayfield Publishing Company)

Paul, R and Linda Elder. *The Art of Socratic Questioning*. Dillon Beach, CA: Foundation for Critical Thinking, 2006.

Rayner, S. *Risk and Relativism in Science for Policy*. In: Johnson B.B., Covello V.T. (eds) *The Social and Cultural Construction of Risk. Technology, Risk, and Society* (An International Series in Risk Analysis), vol 3. Springer, Dordrecht.

Russell, Bertrand. *My Philosophical Development*, Routledge, London 1959.

Saleh, H. ‘State education: Bias towards rote learning stifles critical thinking’, *Financial Times*, October 20th 2013.

Seech, Z. *Open Minds and Everyday Reasoning*, by (Wadsworth Publishing Company).

Sokal, A and Bricmont, J. *Fashionable Nonsense: Postmodern Intellectuals’ Abuse of Science*, Picador, New York, 1998.

Warren, James (ed.). *The Cambridge Companion to Epicureanism* (Cambridge Companions to Philosophy) 1st Edition, 2009.

Weston, A. *A Rulebook for Arguments*, 3rd edition, Hackett Publishing, Cambridge and Indianapolis, 2000.