FOUNDATION OF SCIENCE EDUCATION

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INTRODUCTION

The value of Science is accepted throughout the world. It has attained the status of compulsory subject in the academic institutions of Pakistan from grade 1 to elementary level. It is a comprehensive resource book which would fulfill the needs of the prospective teachers. In this regard, the efforts have been put and hopefully the students of B.Ed will be having benefits in terms of the knowledge and insight as well as they will have a better preparation for examination because the chapters/units as per university course outlines have been included separately. These chapters might be helpful for students of B. Ed as well as prospective teachers of any level in Pakistan.

Muhammad Samiullah
Course Coordinator

Dr. Iqbal Shah
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FOREWORD

The Teacher Education Programs have great significance in the society. The mission of these programs is preparing qualified potential teachers by equipping them up to date knowledge, and skills to teach effectively. Faculty of Education is preparing qualified and competent teachers nation-wide. The faculty and administrators are engaged in the continuous support and strengthening of the mission of Allama Iqbal Open University. The development, improvement, and successful implementation of the Teacher Education programs are also focus of the attention for the Faculty of Education.

Teacher plays a pivotal role in teaching learning process. A teacher must complete some kind of teacher education before becoming a full-time teacher. The quality of student’s success is directly linked with the quality of teaching. Teachers are responsible for developing suitable instructional strategies to facilitate students in order to achieve the curriculum expectations. Teachers also use suitable methods for the assessment and evaluation of students learning. Teachers motivate students and apply variety of teaching and assessment approaches in the classroom, dealing with individual students needs and ensuring sound learning opportunities for every student.

With the explosion of knowledge in all fields of study, there is also an increase in knowledge regarding teaching strategies, pedagogy and assessment techniques. The world is becoming a globalized village. This globalization process and the social changes linked with it demand the introduction of permanent changes and reforms in the educational systems. The teacher’s new role is very crucial. In their new role, teachers should support both the students, parents and society. Teachers should act as guides for their students and facilitate them in their individual progress, taking into consideration the challenges of the globalization process. Science and technology can be helpful in shaping students views about life and learning. Now a days science and technology exist in a broader social and economic context and in turn have a significant impact on society and the environment. Teachers must provide opportunities for students to develop interest for science and technology. They must also ensure that students acquire the knowledge and skills need for safe participation in significant and technological activities. For this, there is need that teachers should be equipped with latest knowledge and skills regarding teaching and learning techniques so that they can cope up successfully with the challenges of latest school programs as well as the challenges from the society.

Keeping in view the latest trends in education, Allama Iqbal Open University has started B.Ed (1.5 years) program. The new foundation of Science Education has been included in this course.

This course has been organized to provide student teachers a comprehensive body of knowledge about various foundations of science education. This course is half credit course comprising 9 Units. Basically this course has been arranged in four blocks; 1. Islamic foundations of science education, 2. Philosophical Foundations of Science Education, 3.
Psychological Foundations of Science Education & 4. Socio economic Foundations of Science Education.

I congratulate Dr. Iqbal Shah, HoD, Department of Science Education, the Course Development Coordinator Dr. Muhammad Samiullah, writers and reviewers of the course who worked hard in the development of this course. All of them worked dedicatedly like a team and completed this task in a highly professional way. I am thankful to Dr. Fazal Ur Rehman Programme Coordinator (B.Ed 1.5 Years) for his dedicated efforts. My special thanks to Prof. Dr. Nasir Mehmood Dean Faculty of Education.

We will welcome comments and suggestions from the teachers and the public for the improvement of this course.

Prof. Dr. Shahid Siddiqui
Vice Chancellor
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Unit 1

ISLAMIC FOUNDATIONS OF SCIENCE EDUCATION

Written by: Dr. Muhammad Samiullah
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INTRODUCTION

In the Muslim world today, most of the focus on the relation between Islam and science involves scientific interpretations of the Quran that claim to show that the sources make prescient statements about the nature of the universe, biological development and other phenomena later confirmed by scientific research, thus demonstrating proof of the divine origin of the Qur'an. Although this issue received widespread support by some, it has been criticized by certain scientists as containing logical fallacies,[1] being unscientific, likely to be contradicted by evolving scientific theories.

In the Muslim world, many believe that modern science was first developed in the Muslim world rather than in Europe and Western countries, that "all the wealth of knowledge in the world has actually emanated from Muslim civilization," and what people call "the scientific method", is actually "the Islamic method." Muslims often cite verse 239 from Surah Al-Baqara — He has taught you what you did not know in support of their view that the Qur'an promotes the acquisition of new knowledge. The modern scientific method was pioneered by Ibn al-Haytham (known in the Western world as "Ablaze"). Robert Briffault, in The Making of Humanity, asserts that the very existence of science, as it is understood in the modern sense, is rooted in the scientific thought and knowledge that emerged in Islamic civilizations during this time. In contrast, some people worry that the contemporary Muslim world suffers from a "profound lack of scientific understanding," and lament that, for example, in countries like Pakistan post-graduate physics students have been known to blame earthquakes on "sinfulness, moral laxity, deviation from the Islamic true path," while "only a couple of muffled voices supported the scientific view that earthquakes are a natural phenomenon unaffected by human activity. As with all other branches of human knowledge, science, from an Islamic standpoint, is the study of nature as stemming from Tawhid, the Islamic conception of the "Oneness" of God. Muslim scientists and scholars have subsequently developed a spectrum of viewpoints on the place of scientific learning within the context of Islam, none of which are universally accepted.

OBJECTIVES

After reading this Unit you will be able to:
1. understand the concept of Quran and science.
2. know about Hadiths and Science.
3. know about Fiqha and Science.
4. understand the concept of Quran, Hadith and Modern Science.
1.1. The Quran and Science

On the 9th of November, 1976, an unusual lecture was given at the French Academy of Medicine. Its title was “Physiological and Embryological data in the Qur’an”. I presented the study based on the existence of certain statements concerning physiology and reproduction in the Qur’an. My reason for presenting this lecture was because it is impossible to explain how a text produced in the seventh century could have contained ideas that have only been discovered in modern times. For the first time, I spoke to members of a learned medical society on subjects whose basic concepts they all knew well, but I could, just as easily, have pointed out statements of a scientific nature contained in the Qur’an and other subjects to specialists from other disciplines. Astronomers, zoologists, geologists and specialists in the history of the earth would all have been struck, just as forcibly as medical doctors, by the presence in the Qur’an of highly accurate reflections on natural phenomena. These reflections are particularly astonishing when we consider the history of science, and can only lead us to the conclusion that they are a challenge to human explanation. There is no human work in existence that contains statements as far beyond the level of knowledge of its time as the Qur’an. Scientific opinions comparable to those in the Qur’an are the result of modern knowledge. In the commentaries to translations of the Qur’an that have appeared in European languages, I have only been able to find scattered and vague references to them. Nor do commentators writing in Arabic provide a complete study of the aspects of the Qur’an that deal with scientific matters. This is why the idea of a comprehensive study of the problem appealed to me. In addition to this, a comparative study of similar data contained in the Bible (Old Testament and Gospels) seemed desirable. Thus, a research project was developed from the comparison of certain passages in the Holy Scriptures of each monotheistic religion with modern scientific knowledge. The project resulted in the publication of a book entitled, The Bible, the Qur’an and Science. The first French edition appeared in May 1976. English and Arabic editions have since been published.

For many centuries, humankind was unable to study certain data contained in the verses of the Qur’an because they did not possess sufficient scientific means. It is only today that numerous verses of the Qur’an dealing with natural phenomena have become comprehensible. A reading of old commentaries on the Qur’an, however knowledgeable their authors may have been in their day, bears solemn witness to a total inability to grasp the depth of meaning in such verses. I could even go so far as to say that, in the 20th century, with its compartmentalization of ever-increasing knowledge, it is still not easy for the average scientist to understand everything he reads in the Qur’an on such subjects, without having recourse to specialized research. This means that to understand all such verses of the Qur’an, one is nowadays required to have an absolutely encyclopedic knowledge embracing many scientific disciplines.

I should like to stress, that I use the word science to mean knowledge which has been soundly established. It does not include the theories which, for a time, help to explain a phenomenon or a series of phenomena, only to be abandoned later on in favor of other explanations. These newer explanations have become more plausible thanks to scientific progress. I only intend to deal with comparisons between statements in the Qur’an and scientific knowledge which are not likely to be subject to further discussion. Wherever I introduce scientific facts which are not yet 100% established, I will make it quite clear.
There are also some very rare examples of statements in the Qur’an which have not, as yet, been confirmed by modern science. I shall refer to these by pointing out that all the evidence available today leads scientists to regard them as being highly probable. An example of this is the statement in the Qur’an that life has an aquatic origin (“And I created every living thing out of water” Qur’an, 21:30). These scientific considerations should not, however, make us forget that the Qur’an remains a religious book par excellence and that it cannot be expected to have a scientific purpose per se. In the Qur’an, whenever humans are invited to reflect upon the wonders of creation and the numerous natural phenomena, they can easily see that the obvious intention is to stress Divine Omnipotence. The fact that, in these reflections, we can find allusions to data connected with scientific knowledge is surely another of God’s gifts whose value must shine out in an age where scientifically based atheism seeks to gain control of society at the expense of the belief in God. But the Qur’an does not need unusual characteristics like this to make its supernatural nature felt. Scientific statements such as these are only one specific aspect of the Islamic revelation which the Bible does not share.

Throughout my research I have constantly tried to remain totally objective. I believe I have succeeded in approaching the study of the Qur’an with the same objectivity that a doctor has when opening a file on a patient. In other words, only by carefully analyzing all the symptoms can one arrive at an accurate diagnosis. I must admit that it was certainly not faith in Islam that first guided my steps, but simply a desire to search for the truth. This is how I see it today. It was mainly the facts which, by the time I had finished my study, led me to see the Qur’an as the divinely-revealed text it really is.

**Authenticity of Qur’an**

Before getting to the essence of the subject, there is a very important point which must be considered: the authenticity of the Qur’an text.

It is known that the text of the Qur’an was both recited from memory, during the time it was revealed, by the Prophet and the believers who surrounded him, and written down by designated scribes among his followers. This process lasted for roughly twenty-three years during which many unofficial copies were made. An official copy was made within one year after the Prophet’s death at the instruction of Caliph Abu Baker.

Here we must note a highly important point. The present text of the Qur’an benefited in its original preparation from the advantage of having its authenticity cross-checked by the text recited from memory as well as the unofficial written texts. The memorized text was of paramount importance at a time when not everyone could read and write, but everybody could memorize. Moreover, the need for a written record was included in the text of the Qur’an itself. The first five verses of chapter al-‘Alaq, which happen to constitute the first revelation made to the Prophet (S), express this quite clearly: “Read: In the name of your Lord who created. Who created man from a clinging entity. Read! Your Lord is the most Noble, Who taught by the pen. Who taught man what he did not know.” Qur’an, 96:1-5 These are surely words in “praise of the pen as a means of human knowledge”, to use Professor Hamidullah’s expression. Then came the Caliphate of ‘Uthman (which lasted from the twelfth to the twenty-fourth year following
Muhammad's death). Within the first two years of Caliph ‘Uthman’s rule, seven official copies were reproduced from the official text and distributed throughout a large area of the world which had already come under Islamic rule. All unofficial copies existing at that time were destroyed and all future copies were made from the official seven copies. In my book, The Bible, the Qur’an and Science, I have quoted passages from the Qur’an which came from the period prior to the Hijrah (the Prophet’s emigration from Makah to Madeenah in the year 622) and which allude to the writing of the Qur’an before the Prophet’s departure from Makkah. There were moreover, many witnesses to the immediate transcription of the Qur’an revelation. Professor Jacques Berque has told me of the great importance he attaches to it in comparison with the long gap separating the writing down of the Judeo-Christian revelation from the facts and events which it relates. Let us not forget that today we also have a number of manuscripts of the first written versions of the Qur’an which were from a time period very close to the time of revelation.

I shall also mention another fact of great importance. We shall examine statements in the Qur’an which today appear to merely record scientific truth, but of which men in former times were only able to grasp the apparent meaning. In some cases, these statements were totally incomprehensible. It is impossible to imagine that, if there were any alterations to the texts, these obscure passages scattered throughout the text of the Qur’an, were all able to escape human manipulation. The slightest alteration to the text would have automatically destroyed the remarkable coherence which is characteristic to them. Change in any text would have prevented us from establishing their total conformity with modern knowledge. The presence of these statements spread throughout the Qur’an looks (to the impartial observer) like an obvious hallmark of its authenticity.

The Qur’an is a revelation made known to humans in the course of twenty-three years. It spanned two periods of almost equal length on either side of the Hijrah. In view of this, it was natural for reflections having a scientific aspect to be scattered throughout the Book. In a study, such as the one we have made, we had to regroup the verses according to subject matter, collecting them chapter by chapter. How should they be classified? I could not find any indications in the Qur’an suggesting any particular classification, so I decided present them according to my own personal one. It would seem to me, that the first subject to deal with is Creation. Here it is possible to compare the verses referring to this topic with the general ideas prevalent today on the formation of the Universe. Next, I divided up verses under the following general headings: Astronomy, the Earth, the Animal and Vegetable Kingdoms, Humans, and Human Reproduction in particular. Furthermore, I thought it useful to make a comparison between Qur’an and Biblical narrations on the same topics from the point of view of modern knowledge. This has been done in the cases of Creation, the Flood and the Exodus. The reason that these topics were chosen is that knowledge acquired today can be used in the interpretation of the texts.

1.2. Hadith and Science
The Qur’an does not constitute the sole source of doctrine and legislation in Islam. During Muhammad’s life and after his death, complementary information of a legislative nature was indeed sought in the study of the words and deeds of the Prophet. Although writing was used in the transmission of Hadith from the very beginning, a lot of this came
also from the oral tradition. Those who undertook to assemble them in collections made the kind of enquiries which are always very taxing before recording accounts of past events. They nevertheless had a great regard for accuracy in their arduous task of collecting information. This is illustrated by the fact that for all of the Prophet's sayings, the most venerable collections always bear the names of those responsible for the account, going right back to the person who first collected the information from members of Muhammad’s family or his companions. A very large number of collections of the Prophet's words and deeds thus appeared under the title of Hadiths. The exact meaning of the word is 'utterances', but it is also customary to use it to mean the narration of his deeds. Some of the collections were made public in the decades following Muhammad’s death. Just over two hundred years were to pass before some of the most important collections appeared. The most authentic record of the facts is in the collections of Al Bukhari and Muslim, which date from over two hundred years after Muhammad and which provide a wider trustworthy account. In recent years, a bilingual Arabic/English edition has been provided by Doctor Muhammad Mushin Khan, of the Islamic University of Madina.[102] Al Bukhara’s work is generally regarded as the most authentic after the Qur'an and was translated into French (1903-1914) by Hondas and Maracas under the title Les Traditions Islamiques (Islamic Traditions). The Hadiths are therefore accessible to those who do not speak Arabic. One must, however, be wary of certain translations made by Europeans, including the French translation, because they contain inaccuracies and untruths which are often more of interpretation than of actual translation. Sometimes, they considerably change the real meaning of a Hadith, to such an extent indeed that they attribute a sense to it which it does not contain.

As regards their origins, some of the Hadiths and Gospels have one point in common which is that neither of them was compiled by an author who was an eyewitness of the events he describes. Nor were they compiled until some time after the events recorded. The Hadiths, like the Gospels, have not all been accepted as authentic. Only a small number of them receive the quasi-unanimous approval of specialists in Muslim Tradition so that, except al-Muwatta, Sahih Muslim and Sahih al-Bukhari, one finds in the same book, Hadiths presumed to be authentic side by side with ones which are either dubious, or should be rejected outright.

In contrast to Canonic Gospels which though questioned by some modern scholars but which have never been contested by Christian high authorities, even those Hadiths that are most worthy to be considered as authentic have been the subject of criticism. Very early in the history of Islam, masters in Islamic thought exercised a thorough criticism of the Hadiths, although the basic book (The Qur'an) remained the book of reference and was not to be questioned. I thought it of interest to delve into the literature of the Hadiths to find out how Muhammad is said to have expressed himself, outside the context of written Revelation, on subjects that were to be explained by scientific progress in following centuries. Al-though Sahih Muslim is also an authentic collection, in this study I have strictly limited myself to the texts of the Hadiths which are generally considered to be the most authentic, i.e. those of Al Bukhari. I have always tried to bear in mind the fact that these texts were compiled by men according to data received from a tradition which was partially oral and that they record certain facts with a greater or lesser degree of accuracy, depending on the individual errors made by those who transmitted the
narrations. These texts are different from other Hadiths which were transmitted by a very large number of people and are unquestionably authentic. I have compared the findings made during an examination of the Hadiths with those already set out in the section on the Qur'an and modern science. The results of this comparison speak for themselves. The difference is in fact quite staggering between the accuracy of the data contained in the Qur'an, when compared with modern scientific knowledge, and the highly questionable character of certain statements in the Hadiths on subjects whose tenor is essentially scientific. These are the only Hadiths to have been dealt with in this study. Hadiths which have as their subject the interpretation of certain verses of the Qur'an sometimes lead to commentaries which are hardly acceptable today. We have already seen the great significance of one verse (sure 36, verse 36) dealing with the Sun which "runs its course to a settled place". Here is the interpretation given of it in a Hadith: "At sunset, the sun . . . prostrates itself underneath the Throne, and takes permission to rise again, and it is permitted and then (a time will come when) it will be about to prostrate itself . . . it will ask permission to go on its course . . . it will be ordered to return whence it has come and so it will rise in the West . . ." (Sahih Al Bukhari). The original text (The Book of the Beginning of the Creation, Vol. IV page 283, part 54, chapter IV, number 421) is obscure and difficult to translate. This passage nevertheless contains an allegory which implies the notion of a course the Sun runs in relation to the Earth: science has shown the contrary to be the case. The authenticity of this Hadith is doubtful (Zanni).

Another passage from the same work (The Book of the Beginning of the Creation, vol. IV page 283, part 54, chapter 6, number 430) estimates the initial stages in the development of the embryo very strangely in time: a forty-day period for the grouping of the elements which are to constitute the human being, another forty days during which the embryo is represented as 'something which clings', and a third forty-day period when the embryo is designated by the term 'chewed flesh'. Once the angels have intervened to define what this individual's future is to be, a soul is breathed into him. This description of embryonic evolution does not agree with modern data.

Whereas the Qur'an gives absolutely no practical advice on the remedial arts, except for a single comment (Sura 16, verse 69) on the possibility of using honey as a therapeutic aid (without indicating the illness involved), the Hadiths devote a great deal of space to these subjects. A whole section of Al Bukhari's collection (part 76) is concerned with medicine. In the French translation by Houdas and Marcais it goes from page 62 to 91 of volume 4, and in Doctor Muhammad Muhsin Khan's bilingual Arabic/English edition from page 395 to 452, of volume VII. There can be no doubt that these pages contain some Hadiths which are conjectural (Zanni), but they are interesting as a whole because they provide an outline of the opinions on various medical subjects that it was possible to hold at the time. One might add to them several Hadiths inserted in other parts of Al Bukhara’s collection which have a medical tenor.

This is how we come to find statements in them on the harms caused by the Evil Eye, witchcraft and the possibility of exorcism; although a certain restriction is imposed on the paid use of the Qur'an for this purpose. There is a Hadith which stresses that certain kinds of date may serve as protection against the effects of magic, and magic may be used against poisonous snakebites. We should not be surprised however to find that at a time
when there were limited possibilities for the scientific use of drugs, people were advised to rely on simple practices; natural treatments such as blood-letting, cupping, and cauterization, head-shaving against lice, the use of camel's milk and certain seeds such as black cumin, and plants such as Indian Quest. It was also recommended to burn a mat made of palm-tree leaves and put the ash from it into a wound to stop bleeding. In emergencies, all available means that might genuinely be of use had to be employed. It does not seem a priori-to be a very good idea, however, to suggest that people drink camel's urine. It is difficult today to subscribe to certain explanations of subjects related to various illnesses. Among them, the following might be mentioned: the origins of a fever. there are four statements bearing witness to the fact that "fever is from the heat of hell" (Al Bukhari, The Book of Medicine, vol. VII, chapter 28, page 396). This concept is illustrated by the Hadith of the Fly. "If a fly falls into the vessel of any of you, let him dip all of it (into the vessel) and then throw it away, for in one of its wings there is a disease and in the other there is healing (antidote for it). i.e. the treatment for that disease" (Ibid. chapter 15-16, pages 462-463, also The Book of the Beginning of Creation part 54, chapters 15 & 16.) abortion provoked by the sight of a snake (which can also blind). This is mentioned in The Book of the Beginning of Creation, Vol. IV (chapter 13 and 14, pages 330 & 334). hemorrhages between periods. The Book of Menses (Menstrual Periods) Vol. VI, part 6, pages 490 & 495 contains two Hadiths on the cause of hemorrhages between periods (chapters 21 & 28). They refer to two women: in the case of the first, there is a description (undetailed) of the symptoms, with a statement that the hemorrhage comes from a blood vessel; in the second, the woman had experienced hemorrhages between periods for seven years, and the same vascular origin is stated. One might suggest hypotheses as to the real causes of the above, but it is not easy to see what arguments could have been produced at the time to support this diagnosis. This could nevertheless have been quite accurate. The statement that diseases are not contagious. Al Bukhari's collection of hadiths refers in several places (chapters 19, 25, 30, 31, 53 and 54, Vol. VII, part 76, of the Book of Medicine) to certain special cases, e.g. leprosy (page 408), plague (pages 418 & 422), camel's scabies (page 447), and also provides general statements. The latter are however placed side by side with glaringly contradictory remarks: it is recommended, for example, not to go to areas where there is plague, and to stay away from lepers. Consequently, it is possible to conclude that certain hadiths exist which are scientifically unacceptable. There is a doubt surrounding their authenticity. The purpose of reference to them lies solely in the comparison that they occasion with the verses of the Qur'an mentioned above: these do not contain a single inaccurate statement. This observation clearly has considerable importance. One must indeed remember that at the Prophet's death, the teachings that were received from this fell into two groups:-firstly, a large number of Believers knew the Qur'an by heart because, like the Prophet, they had recited it many, many times; transcriptions of the text of the Qur'an already existed moreover, which were made at the time of the Prophet and even before the Hegira-secondly, the members of his following who were closest to him and the Believers who had witnessed his words and deeds had remembered them and relied on them for support, in addition to the Qur'an, when defining a nascent doctrine and legislation.
In the years that were to follow the Prophet's death, texts were to be compiled which recorded the two groups of teachings he had left. The first gathering of hadiths was performed roughly forty years after the Hegira, but a first collection of Qur'an texts had been made beforehand under Caliph Abu Baker, and in particular Caliph Uthman ﷺ, the second of whom published a definitive text during his Caliphate, i.e. between the twelfth and twenty-fourth years following Muhammad's ﷺ death. What must be heavily stressed is the disparity between these two groups of texts, both from a literary point of view and as regards their contents. It would indeed be unthinkable to compare the style of the Qur'an with that of the hadiths. What is more, when the contents of the two texts are compared in the light of modern scientific data, one is struck by the oppositions between them. I hope I have succeeded in showing what follows: on the one hand, statements in the Qur'an which often appear to be commonplace, but which conceal data that science was later to bring to light. On the other hand, certain statements in the hadiths which are shown to be in absolute agreement with the ideas of their times but which contain opinions that are deemed scientifically unacceptable today. These occur in an aggregate of statements concerning Islamic doctrine and legislation, whose authenticity is unquestioningly acknowledged.

Finally, it must be pointed out that Muhammad's ﷺ own attitude was quite different towards the Qur'an from what it was towards his personal sayings. The Qur'an was proclaimed by him to be a divine Revelation. Over a period of twenty years, the Prophet classified its sections with the greatest of care, as we have seen. The Qur'an represented what had to be written down during his own lifetime and learned by heart to become part of the liturgy of prayers. The hadiths are said, in principle, to provide an account of his deeds and personal reflections, but he left it to others to find an example in them for their own behaviour and to make them public however they liked: he did not give any instructions. In view of the fact that only a limited number of hadiths may be considered to express the Prophet's thoughts with certainty, the others must contain the thoughts of the men of his time, in particular with regard to the subjects referred to here. When these dubious or inauthentic hadiths are compared to the text of the Qur'an, we can measure the extent to which they differ. This comparison highlights (as if there were still any need to) the striking difference between the writings of this period, which are riddled with scientific inaccurate statements, and the Qur'an, the Book of Written Revelation, that is free from errors of this kind.

1.3. Fiqh and Science
The word *Fiqh* is an Arabic term meaning "deep understanding" or "full comprehension". Technically it refers to the body of Islamic law extracted from detailed Islamic sources (which are studied in the principles of Islamic jurisprudence) and the process of gaining knowledge of Islam through jurisprudence. The historian Ibn Khaldun describes *fiqh* as "knowledge of the rules of God which concern the actions of persons who own themselves bound to obey the law respecting what is required (wajib), sinful (haraam), recommended (mandūb), disapproved (makrūh) or neutral (mubah)". This definition is consistent amongst the jurists.

In Modern Standard Arabic, *fiqh* has come to mean jurisprudence in general, be it Islamic or secular. It is thus possible to speak of Chief Justice John G. Roberts, Jr. as an
expert in the common law *fiqh* of the United States, or of Abdel Razzaq El sanhouri Pasha as an expert in the civil law *fiqh* of Egypt.

The most important sources of *fiqh* in order of importance are:
1. The Qur'an
2. Hadith
3. Ijma, i.e. collective reasoning and consensus amongst authoritative Muslims of a particular generation, and its interpretation by Islamic scholars.
4. Qiyas, i.e. analogy which is deployed if *Ijma* or historic collective reasoning on the issue is not available.

The Qur'an gives clear instructions on many issues, such as how to perform the ritual purification (*wudu*) before the obligatory daily prayers (*salat*), but on other issues, some Muslims believe the Qur'an alone is not enough to make things clear. For example, the Qur'an states one needs to engage in daily prayers (*salat*) and fast (*sawm*) during the month of Ramadan but Muslims believe they need further instructions on how to perform these duties. Details about these issues can be found in the traditions of *Muhammad* ﷺ, so Qur'an and Sunnah are in most cases the basis for (*Shariah*).

Some topics are without precedent in Islam's early period. In those cases, Muslim jurists (*Fuqaha*) try to arrive at conclusions by other means. Sunni jurists use historical consensus of the community (*Ijma*); a majority in the modern era also use analogy (*Qiyas*) and weigh the harms and benefits of new topics (*Istislah*), and a plurality utilizes juristic preference (*Istihsan*). The conclusions arrived at with the aid of these additional tools constitute a wider array of laws than the Sharia consists of, and is called *fiqah*. Thus, in contrast to the *sharia*, *fiqah* is not regarded as sacred and the schools of thought have differing views on its details, without viewing other conclusions as sacrilegious. This division of interpretation in more detailed issues has resulted in different schools of thought (*madh'hab*). This wider concept of *Islamic jurisprudence* is the source of a range of laws in different topics that guide Muslims in everyday life.

### 1.4. The Quran, Hadith and Modern Science

One of harmony and not of discord. A confrontation between a religious book and the secular ideas proclaimed by science is perhaps, in the eyes of many people today, something of a paradox. The majority of today’s scientists, with a small number of exceptions of course, is indeed bound up in materialist theories, and has only indifference or contempt for religious questions which they often consider to be founded on legend. In the West moreover, when science and religion are discussed, people are quite willing to mention Judaism and Christianity among the religions referred to, but they hardly ever think of Islam. So many false judgments based on inaccurate ideas have indeed been made about it, that today it is The relationship between the Quran and science is *a priori* a surprise, especially when it turns out to be very difficult to form an exact notion of the reality of Islam. As a prelude to any confrontation between the Islamic Revelation and science, it would seem essential that an outline be given of a religion that is so little known in the West.
The totally erroneous statements made about Islam in the West are sometimes the result of ignorance, and sometimes of systematic denigration. The most serious of all the untruths told about it are however those dealing with facts; for while mistaken opinions are excusable, the presentation of facts running contrary to the reality is not. It is disturbing to read blatant untruths in eminently respectable works written by authors who a priori are highly qualified. The following is an example taken from the *Universalism Encyclopedia* (Encyclopedia Universalism) vol. 6. Under the heading Gospels (Evangels) the author alludes to the differences between the latter and the Quran: "The evangelists (...) do not (...), as in the Quran, claim to transmit an autobiography that God miraculously dictated to the Prophet.". In fact, the Quran has nothing to do with an autobiography; it is a preaching; a consultation of even the worst translation would have made that clear to the author. The statement we have quoted is as far from reality as if one were to define a Gospel as an account of an evangelist's life. The person responsible for this untruth about the Quran is a professor at the Jesuit Faculty of Theology, Lyon! The fact that people utter such untruths helps to give a false impression of the Quran and Islam.

There is hope today however because religions are no longer as inward-looking as they were and many of them are seeking for mutual understanding. One must indeed be impressed by a knowledge of the fact that an attempt is being made on the highest level of the hierarchy by Roman Catholics to establish contact with Muslims; they are trying to fight incomprehension and are doing their utmost to change the inaccurate views on Islam that are so widely held.

Al-Qur'an, the main source of the Islamic faith, is a book believed by Muslims, to be of completely Divine origin. Muslims also believe that it contains guidance for all mankind. Since the message of the Qur'an is believed to be for all times, it should be relevant to every age. Does the Qur'an pass this test? In this booklet, I intend to give an objective analysis of the Muslim belief regarding the Divine origin of the Qur'an, in the light of established scientific discoveries. There was a time, in the history of world civilization, when ‘miracles’, or what was perceived to be a miracle, took precedence over human reason and logic. But how do we define the term ‘miracle’? A miracle is anything that takes place out of the normal course of life and for which humankind has no explanation. However, we must be careful before we accept something as a miracle. An article in ‘The Times of India’ Mumbai, in 1993 reported that ‘a saint’ by the name ‘Baba Pilot’ claimed to have stayed continuously submerged under water in a tank for three consecutive days and nights. However, when reporters wanted to examine the base of the tank of water where he claimed to have performed this ‘miraculous’ feat, he refused to let them do so. He argued by asking as to how one could examine the womb of a mother that gives birth to a child. The ‘Baba’ was hiding something. It was a gimmick simply to gain publicity.

**Self Assessment Exercise**

Q.1: Elaborate how Quran and Science are related?
Q.2: How Hadiths is in support of Science? Support your answer with the help of examples.
Q.3: Explain proofs of Modern Science in the light of Quran and Hadiths.
Q.4: Write important sources of Science Knowledge.
Unit 2

ISLAMIC FOUNDATIONS OF SCIENCE EDUCATION

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INTRODUCTION

Where does learning processes go? What destination has education? Is education and learning process value free? There are many such questions that could not be ignored without coasts. We always think that by learning and education we could make desired favorable changes in young generation and thus we would shape our society and cultures. Knowledge and learning is itself a value. But careful contemplation reveals that there are values that knowledge itself has to follow them. Knowledge is considered as weapon without proper guidance may lead to disaster. It is a light when handed over to a thief, help in robbery. It is essential that we value education and realize that it can open doors for our young people. Education and its role in aiding young people to become good citizens are at the centre of public debate in many countries. Our young people are losing their way and falling victim to drugs, violence, prison, unemployment, and poor education. The feeling of loneliness depression must be added tog and working together for brighter future for our young people. The absence of holistic view in education is evident and any serious attempt to overcome such problem as mentioned above has to pay effective attention to religion. Educational values and purpose could not be achieved if the knowledge of the essence of human purpose on earth is excluded or sidelined from education curriculum. Campuses are not isolated from the wider societies.

OBJECTIVES

After reading this Unit you will be able to:
1. know about golden age of Muslim Science and Technology.
2. know the contributions of Muslims in Science.
3. understand the concept of science and Technology in Muslim World.
4. know about rebirth of science and technology in the Muslim world.


2.1. The Golden Age of Muslim Science and Technology
Science, technology, and other fields of knowledge developed rapidly during the golden age of Islam from the eighth to the 13th century and beyond. Early Abbasid caliphs embarked on major campaigns seeking scientific and philosophical works from eastern and western worlds. Baghdad, the capital of the Abbasid Empire, became the center of intellectual and scientific activity. The first academy, Bait al-Hikmah (House of Wisdom) was established by the Abbasid caliph Harun al-Rashid and was expanded by his son the caliph al-Mammon (d. 833). By the ninth century, Baghdad had become a center of financial power and political prestige and intellectual pursuits flourished in numerous colleges, schools, hospitals, mosques, and libraries. Baghdad attracted visitors, ambassadors, and students from all parts of the empire.

The Beginning
During the seventh century the Arab empire and Islamic domain included the realm of the Old Persian Empire and most of the Byzantine Empire. This resulted in access to the wealth and heritage of both Hellenistic and Eastern philosophy and knowledge.

During the immediate pre-Islamic period (fifth–seventh centuries), Hellenistic science and knowledge passed to the Arab people through Alexandria in Egypt, Namibia in Syria, and Antioch and Edessa in northern Mesopotamia and Asia Minor. Through these centers much Greek philosophy and science was preserved by Coptic, Nestorian (Eastern Orthodox), and Jacobite Christians.

In Persia, Jundi-Shapur was another important pre-Islamic center for the quest of scientific knowledge. It was established during the Tasmanian period and was located in Khuzestan, not far from the Abbasid capital of Baghdad. Home to many Nestorian and Zoroastrian scholars, it was conquered by the Arabs in 636. Abbasid caliphs summoned many of these scholars to serve on the faculty of the newly established Bait al-Hikmah.

Harran was another important intellectual center. Situated in eastern Anatolia, Harran was a center for Saharans, a pre-Christian monotheistic Semitic people who preserved both Babylonian and Hellenistic heritages. Therefore several agencies worked to develop and extend Hellenistic and Eastern heritage.

Quest for Learning
During the seventh and eighth centuries as Arabs conquered new lands they preserved, assimilated, and transformed the cultures of their subjects. Beside the Arabic speaking scholars there were also Nestorians with knowledge of Greek and Syrian languages (dialect of Aramaic), Saharans who spoke a dialect of Aramaic, Zoroastrians who used Pahlavi (an old Persian language related to Aramaic), Indians knowledgeable in Sanskrit, and Jews fluent in Hebrew. However Arabic was the literary language of both.
2.2. Muslim Contributions in Medicine, Science & Technology

The contributions in the advancement of knowledge by the traditional Islamic institutions of learning (Maracas, Maktab, Halqa & Dar-ul-Abloom) are enormous, which have been summed up in Encyclopedia Britannica: “The madrasahs generally offered instruction in both the religious sciences and other branches of knowledge. The contribution of these institutions to the advancement of knowledge was vast.

Muslim scholars calculated the angle of the ecliptic; measured the size of the Earth; calculated the precession of the equinoxes; explained, in the field of optics and physics, such phenomena as refraction of light, gravity, capillary attraction, and twilight; and developed observatories for the empirical study of heavenly bodies. They made advances in the uses of drugs, herbs, and foods for medication; established hospitals with a system of interns and externs; discovered causes of certain diseases and developed correct diagnoses of them; proposed new concepts of hygiene; made use of anesthetics in surgery with newly innovated surgical tools; and introduced the science of dissection in anatomy.

Muslims furthered the scientific breeding of horses and cattle; found new ways of grafting to produce new types of flowers and fruits; introduced new concepts of irrigation, fertilization, and soil cultivation; and improved upon the science of navigation. In the area of chemistry, Muslim scholarship led to the discovery of such substances as potash, alcohol, nitrate of silver, nitric acid, sulfuric acid, and mercury chloride.

Muslims scientists also developed to a high degree of perfection the arts of textiles, ceramics, and metallurgy.” According to a US study published by the American Association for the Advancement of Science in its Journal on 21 February 2007; ‘Designs on surface tiles in the Islamic world during the Middle Ages revealed their maker’s understanding of mathematical concepts not grasped in the West until 500 years later. Many Medieval Islamic buildings walls have ornate geometric star and polygon or ‘girth’, patterns, which are often overlaid with a swirling network of lines – This girth tile method was more efficient and precise than the previous approach, allowing for an important breakthrough in Islamic mathematics and design.’

Muslims Scholars of Theology and Science:

According to the famous scientist Albert Einstein; “Science without religion is lame. Religion without science is blind.” Francis Bacon, the famous philosopher, has rightly said that a little knowledge of science makes you an atheist, but an in-depth study of science makes you a believer in God. A critical analysis reveals that most of Muslim scientists and scholars of medieval period were also eminent scholars of Islam and theology. The earlier Muslim scientific investigations were based on the inherent link between the physical and the spiritual spheres, but they were informed by a process of careful observation and reflection that investigated the physical universe.

Influence of Qur’an on Muslims Scientists:

The worldview of the Muslims scientists was inspired by the Qur’an and they knew that: “Surely, In the creation of the heavens and the earth; in the alternation of the night and
the day, in the sailing of the ships through the ocean for the profit of mankind; in the rain which Allah sends down from the skies, with which He revives the earth after its death and spreads in it all kinds of animals, in the change of the winds and the clouds between the sky and the earth that are made subservient, there are signs for rational people.” (Qur’an; 2:164). “Indeed in the alternation of the night and the day and what Allah has created in the heavens and the earth, there are signs for those who are God fearing.” (Qur’an; 10:6). They were aware that there was much more to be discovered. They did not have the precise details of the solar and lunar orbits but they knew that there was something extremely meaningful behind the alternation of the day and the night and in the precise movements of the sun and the moon as mentioned in Qur’an: One can still verify that those who designed the dome and the minaret, knew how to transform space and silence into a chanting remembrance that renews the nexus between God and those who respond to His urgent invitation.

Famous Muslim Scientists and Scholars:
The traditional Islamic institutions of learning produced numerous great theologians, philosophers, scholars and scientists. Their contributions in various fields of knowledge indicate the level of scholarship base developed among the Muslims one thousand years ago. Only few are being mentioned here:

Chemistry:
Jabir ibn Hayyan, Abu Musa (721-815), alchemist known as the “father of chemistry.” He studied most branches of learning, including medicine. After the ‘Abbasids defeated the Umayyads, Jabir became a court physician to the ‘Abbasid caliph Harun ar-Rashid. Jabir was a close friend of the sixth Shi‘ite imam, Ja‘far ibn Muhammad, whom he gave credit for many of his scientific ideas.

Mathematics, Algebra, Astronomy & Geography:
Al-Khwarizmi (Algorizm) (770–840 C.E) was a researcher of mathematics, algorithm, algebra, calculus, astronomy & geography. He compiled astronomical tables, introduced Indian numerals (which became Arabic numerals), formulated the oldest known trigonometric tables, and prepared a geographic encyclopaedia in cooperation with 69 other scholars.

Physics, Philosophy, Medicine:
Ibn Ishaq Al-Kindi (Alkindus) (800–873 C.E) was an intellectual of philosophy, physics, optics, medicine, mathematics & metallurgy. Ali Ibn Rabban Al-Tabari(838–870 C.E) was a scholar in medicine, mathematics, calligraphy & literature. Al-Razi (Rhazes) (864– 930 C.E), a physical and scientist of medicine, ophthalmology, smallpox, chemistry & astronomy.

Ar-Razi’s two most significant medical works are the Kitab al-Mansuri, which became well known in the West in Gerard of Cremona’s 12th-century Latin translation; and ‘Kitab al-hawi’, the “Comprehensive Book”. Among his numerous minor medical
treatises is the famed Treatise on the Small Pox and Measles, which was translated into Latin, Byzantine Greek, and various modern languages.

Al-Farabi (Al-Pharabius) (870-950 C.E) excelled in sociology, logic, philosophy, political science & music. Abu Al-Qasim Al-Zahravi (Albucasis; 936 -1013 C.E) was an expert in surgery & medicine known as the father of modern surgery.

Ibn Al-Haitham (Alhazen) (965-1040 C.E); was the mathematician and physicist who made the first significant contributions to optical theory since the time of Ptolemy (flourished 2nd century). In his treatise on optics, translated into Latin in 1270 as Opticae thesaurus Alhazeni libri vii, Alhazen published theories on refraction, reflection, binocular vision, focusing with lenses, the rainbow, parabolic and spherical mirrors, spherical aberration, atmospheric refraction, and the apparent increase in size of planetary bodies near the Earth’s horizon. He was first to give an accurate account of vision, correctly stating that light comes from the object seen to the eye.

Abu Raihan Al-Biruni (973-1048 C.E); was a Persian scholar and scientist, one of the most learned men of his age and an outstanding intellectual figure. Al-Biruni’s most famous works are Athar al-baqiyah (Chronology of Ancient Nations); at-Tafhim (“Elements of Astrology”); al-Qanun al-Mas’udi (“The Mas’udi Canon”), a major work on astronomy, which he dedicated to Sultan Mas’ud of Ghazna; Ta’rikh al-Hind (“A History of India”); and Kitab as-Saydalah, a treatise on drugs used in medicine. In his works on astronomy, he discussed with approval the theory of the Earth’s rotation on its axis and made accurate calculations of latitude and longitude. He was the first one to determine the circumference earth. In the field of physics, he explained natural springs by the laws of hydrostatics and determined with remarkable accuracy the specific weight of 18 precious stones and metals. In his works on geography, he advanced the daring view that the valley of the Indus had once been a sea basin.

Ibn Sina (Avicenna, 981–1037 C.E); was a scientist of medicine, philosophy, mathematics & astronomy. He was particularly noted for his contributions in the fields of Aristotelian philosophy and medicine. He composed the Kitab ash-shifa’ (“Book of Healing”), a vast philosophical and scientific encyclopedia, and the Canon of Medicine, which is among the most famous books in the history of medicine.

Ibn Hazm, (994-1064 C.E) was a Muslim litterateur, historian, jurist, and theologian of Islamic Spain. One of the leading exponents of the Zahiri (literalist) school of jurisprudence, he produced some 400 works, covering jurisprudence, logic, history, ethics, comparative religion, and theology, and The Ring of the Dove, on the art of love.

Al-Zarqali (Arzachel) (1028-1087 C.E); an astronomer who invented astrolabe (an instrument used to make astronomical measurements). Al-Ghazali (Algazel) (1058-1111 C.E); was a scholar of sociology, theology & philosophy.

Ibn Zuhr (Avenzoar) (1091-1161 C.E); was a scientist and expert in surgery & medicine.
Ibn Rushd (Averroes) (1128-1198 C.E); excelled in philosophy, law, medicine, astronomy & theology.

Nasir Al-Din Al-Tusi (1201-1274 C.E); was the scholar of astronomy and Non-Euclidean geometry.

Geber (flourished in 14th century Spain) is author of several books that were among the most influential works on alchemy and metallurgy during the 14th and 15th centuries. A number of Arabic scientific works credited to Jabir were translated into Latin during the 11th to 13th centuries. Thus, when an author who was probably a practicing Spanish alchemist began to write in about 1310. Four works by Geber are known: Summa perfectionis magisterii (The Sum of Perfection or the Perfect Magistery, 1678), Liber fornacum (Book of Furnaces, 1678), De investigatione perfectionis (The Investigation of Perfection, 1678), and De inventione veritatis (The Invention of Verity, 1678).

They are the clearest expression of alchemical theory and the most important set of laboratory directions to appear before the 16th century. Accordingly, they were widely read and extremely influential in a field where mysticism, secrecy, and obscurity were the usual rule. Geber’s rational approach, however, did much to give alchemy a firm and respectable position in Europe. His practical directions for laboratory procedures were so clear that it is obvious he was familiar with many chemical operations. He described the purification of chemical compounds, the preparation of acids (such as nitric and sulfuric), and the construction and use of laboratory apparatus, especially furnaces. Geber’s works on chemistry were not equaled in their field until the 16th century with the appearance of the writings of the Italian chemist Vannoccio Biringuccio, the German mineralogist Georgius Agricola, and the German alchemist Lazarus Ercker.

Muhammad Ibn Abdullah (Ibn Battuta) (1304-1369 C.E); was a world traveler, he traveled 75,000 mile voyage from Morocco to China and back. Ibn Khaldun (1332-1395 C.E) was an expert on sociology, philosophy of history and political science.

Tipu, Sultan of Mysore (1783-1799 C.E) in the south of India, was the innovator of the world’s first war rocket. Two of his rockets, captured by the British at Srirangapatana, are displayed in the Woolwich Museum of Artillery in London. The rocket motor casing was made of steel with multiple nozzles. The rocket, 50mm in diameter and 250mm long, had a range performance of 900 meters to 1.5 km.

Turkish scientist Hassarfen Ahmet Celebi took off from Galata tower and flew over the Bosphorus, two hundred years before a comparable development elsewhere. Fifty years later Logari Hasan Celebi, another member of the Celebi family, sent the first manned rocket into upper atmosphere, using 150 okka (about 300 pounds) of gunpowder as the firing fuel.
Contribution of Great Muslim Women & Scholars:

Islam does not restrict acquisition of knowledge to men only; the women are equally required to gain knowledge. Hence many eminent women have contributed in different fields. Aishah as-Siddiqah (the one who affirms the Truth), the favourite wife of Prophet Muhammad (peace be upon him), is regarded as the best woman in Islam. Her life also substantiates that a woman can be a scholar, exert influence over men and women and provide them with inspiration and leadership. Her life is also an evidence of the fact that the same woman can be totally feminine and be a source of pleasure, joy and comfort to her husband. The example of Aishah in promoting education and in particular the education of Muslim women in the laws and teachings of Islam is one which needs to be followed. She is source of numerous Hadith and has been teaching eminent scholars. Because of the strength of her personality, she was a leader in every field in knowledge, in society and in politics.

Sukayna (also Sakina), the great granddaughter of the Prophet (peace be upon him), and daughter of Imam Husain was the most brilliant most accomplished and virtuous women of her time. She grew up to be an outspoken critic of the Umayyads. She became a political activist, speaking against all kinds of tyranny and personal, social and political iniquities and injustice. She was a fiercely independent woman. She married more than once, and each time she stipulated assurance of her personal autonomy, and the condition of monogamy on the prospective husband’s part, in the marriage contract. She went about her business freely, attended and addressed meetings, received men of letters, thinkers, and other notables at her home, and debated issues with them. She was an exceedingly well-educated woman who would take no nonsense from anyone howsoever high and mighty he or she might be.

Um Adhah al-Adawiyyah (d. 83 AH), reputable scholar and narrator of Hadith based on reports of Ali ibn Abu Talib and Ayesha; Amrah bint Abd al-Rahman (d. 98 AH), one of the more prominent students of Ayesha and a known legal scholar in Madina whose opinions overrode those of other jurists of the time; Hafsa bint Sirin al-Ansariyyah (d. approx. 100 AH), also a legal scholar. Amah al-Wahid (d. 377 AH), noted jurist of the Shafaii school and a mufti in Baghdad; Karimah bint Ahmad al-Marwaziyyah (d. 463 AH), teacher of hadith (Sahih Bukhari); Zainab bint Abd al-Rahman (d. 615 AH), linguist and teacher of languages in Khorasan. Zainab bint Makki (d. 688 AH) was a prominent scholar in Damascus, teacher of Ibn Taimiya, the famous jurist of the Hanbali school; Zaynab bint Umar bin Kindi (d. 699 AH), teacher of the famous hadith scholar, al-Mizzi; Fatima bint Abbas (d. 714 AH), legal scholar of the Hanbali school, mufti in Damascus and later in Cairo; Nafisin bint al Hasan taught hadith; Imam Shafaii sat in her teaching circle at the height of his fame in Egypt. Two Muslim women — Umm Isa bint Ibrahim and Amat al-Wahid — served as muftis in Baghdad. Ayesha al-Banniyyah, a legal scholar in Damascus, wrote several books on Islamic law. Umm al-Banin (d. 848 AH/1427 CE) served as a mufti in Morocco. Al Aliyya was a famous teacher whose classes’ men attended before the noon prayer (Zuhr) and women after the afternoon prayer (Asr). A Muslim woman of the name of Rusa wrote a textbook on medicine, and another, Ujliyyah bint al-Ijli (d. 944 CE) made instruments to be used by astronomers. During the
Mamluk period in Cairo (11th century) women established five universities and 12 schools which women managed.

Rabi’a al-Adawiyya al-Basri (717 C.E), is honored as one of the earliest and greatest sufis in Islam. Orphaned as a child, she was captured and sold into slavery. But later her master let her go. She retreated into the desert and gave herself to a life of worship and contemplation. She did not marry, and to a man who wanted her hand she said: “I have become naught to self and exist only through Him. I belong wholly to Him. You must ask my hand of Him, not of me.” She preached unselfish love of God, meaning that one must love Him for His own sake and not out of fear or hope of rewards. She had many disciples, both men and women.

Zubaida (Amatal Aziz bint Jafar), the favourite wife of Harun al-Rashid, the legendary Abassid caliph. She came to be an exceedingly wealthy woman, a billionaire so to speak, independently of her husband. Granddaughter of Al-Mansur, she grew up to be a lady of dazzling beauty, articulate and charming of speech, and great courage. Discerning and sharp, her wisdom and insightfulness inspired immediate admiration and respect. In her middle years she moved out of the royal “harem” and began living in a huge palace of her own. She owned properties all over the empire which dozens of agents in her employ managed for her. A cultivated woman, pious and well acquainted with the scriptures, Zubaida was also a poetess and a patron of the arts and sciences. She allocated funds to invite hundreds of men of letters, scientists, and thinkers from all over the empire to locate and work in Baghdad. She spent much of her funds for public purposes, built roads and bridges, including a 900-mile stretch from Kufa to Makkah, and set up, hostels, eating places, and repair shops along the way, all of which facilitated travel and encouraged enterprise. She built canals for both irrigation and water supply to the people. She spent many millions of Dinars on getting a canal built, that went through miles of tunnel through mountains, to increase the water supply in Makkah for the benefit of pilgrimages. She took a keen interest in the empire’s politics and administration. The caliph himself sought her counsel concerning the affairs of state on many occasions and found her advice to be eminently sound and sensible. After Harun’s death, his successor, Al Mamun, also sought her advice from time to time. She died in 841 C.E (32 years after Harun’s death).

Arwa bint Ahmad bin Mohammad al-Sulayhi (born 1048 C.E) was the ruling queen of Yemen for 70 years (1067-1138 C.E), briefly, and that only technically, as a co-ruler with her two husbands, but as the sole ruler for most of that time. She is still remembered with a great deal of affection in Yemen as a marvellous queen. Her name was mentioned in the Friday sermons right after that of the Fatimid caliph in Cairo. She built mosques and schools throughout her realm, improved roads, took interest in agriculture and encouraged her country’s economic growth. Arwa is said to have been an extremely beautiful woman, learned, and cultured. She had a great memory for poems, stories, and accounts of historical events. She had good knowledge of the Qur’an and Sunnah. She was brave, highly intelligent, devout, with a mind of her own. She was a Shi’a of the Ismaili persuasion, sent preachers to India, who founded an Ismaili community in Gujarat.
which still thrives. She was also a competent military strategist. At one point (1119 C.E) the Fatimid caliph sent a general, Najib ad-Dowla, to take over Yemen. Supported by the emirs and her people, she fought back and forced him to go back to Egypt. She died in 1138 C.E at the age of 90. A university in Sana’a is named after her, and her mausoleum in Jibla continues to be a place of pilgrimage for Yemenis and others. The other eminent ladies who played important role in the affairs of state and philanthropy include, Buran the wife of Caliph Mamun. Among the Mughals Noor Jehan, Zaib un Nisa left their mark in Indian history. Razia Sultan was another eminent women ruler in India.

**Influence of Islamic Learning in Reviving Western Civilization:**
While Muslims were excelling in the field of knowledge and learning of science and technology, the conditions of Christendom at this period was deplorable. Under Constantine and his orthodox successors the Aesclepios were closed for ever, the public libraries established by liberality of the pagan emperors were dispersed or destroyed. Learning was branded as magic and punished as treason, philosophy and science were exterminated. The ecclesiastical hatred against human learning had found expression in the patristic maxims; “Ignorance is the mother of devotion” and Pope Gregory the Great the founder of the doctrine of ‘supremacy of religious authority’; gave effect to this obscurantist dogma by expelling from Rome all scientific studies and burning the Palatine Library founded by Augustus Caesar. He forbade the study of ancient writers of Greece and Rome. He introduced and sanctified the mythological Christianity which continued for centuries as the predominating creed of Europe with its worship of relics and the remains of saints. Science and literature were placed under the ban by orthodox Christianity and they succeeded in emancipating themselves only when Free Thought had broken down the barriers raised by orthodoxy against the progress of the human mind.

**Phenomenal influence of Islamic learning on the West:**
The influence of Islamic learning on the West has been phenomenal; an extract from Encyclopedia Britannica is an eye opener for the Muslims:

“The decline of Muslim scholarship coincided with the early phases of the European intellectual awakening that these translations were partly instrumental in bringing about. The translation into Latin of most Islamic works during the 12th and 13th centuries had a great impact upon the European Renaissance. As Islam was declining in scholarship and Europe was absorbing the fruits of Islam’s centuries of creative productivity, signs of Latin Christian awakening were evident throughout the European continent. The 12th century was one of intensified traffic of Muslim learning into the Western world through many hundreds of translations of Muslim works, which helped Europe seize the initiative from Islam when political conditions in Islam brought about a decline in Muslim scholarship. By 1300 C.E when all that was worthwhile in Muslim scientific, philosophical, and social learning had been transmitted to European schoolmen through Latin translations, European scholars stood
once again on the solid ground of Hellenistic thought, enriched or modified through Muslim and Byzantine efforts.”

“Most of the important Greek scientific texts were preserved in Arabic translations. Although the Muslims did not alter the foundations of Greek science, they made several important contributions within its general framework. When interest in Greek learning revived in western Europe during the 12th and 13th centuries, scholars turned to Islamic Spain for the scientific texts. A spate of translations resulted in the revival of Greek science in the West and coincided with the rise of the universities. Working within a predominantly Greek framework, scientists of the late Middle Ages reached high levels of sophistication and prepared the ground for the scientific revolution of the 16th and 17th centuries.” According to Will Durant, the Western scholar, “For five centuries, from 700 to 1200 (C.E), Islam led the world in power, order and extent of government, in refinement of manners, scholarship and philosophy”.

2.3. Decline of Science and Technology in the Muslim World
On temporary Islam is not known for its engagement in the modern scientific project. But it is heir to a legendary “Golden Age” of Arabic science frequently invoked by commentators hoping to make Muslims and Westerners more respectful and understanding of each other. President Obama, for instance, in his June 4, 2009 speech in Cairo, praised Muslims for their historical scientific and intellectual contributions to civilization:

It was Islam that carried the light of learning through so many centuries, paving the way for Europe’s Renaissance and Enlightenment. It was innovation in Muslim communities that developed the order of algebra; our magnetic compass and tools of navigation; our mastery of pens and printing; our understanding of how disease spreads and how it can be healed.

Such tributes to the Arab world’s era of scientific achievement are generally made in service of a broader political point, as they usually precede discussion of the region’s contemporary problems. They serve as an implicit exhortation: the great age of Arab science demonstrates that there is no categorical or congenital barrier to tolerance, cosmopolitanism, and advancement in the Islamic Middle East.

To anyone familiar with this Golden Age, roughly spanning the eighth through the thirteenth centuries A.D., the disparity between the intellectual achievements of the Middle East then and now — particularly relative to the rest of the world — is staggering indeed. In his 2002 book what went wrong?, historian Bernard Lewis notes that “for many centuries the world of Islam was in the forefront of human civilization and achievement.” “Nothing in Europe,” notes Jamil Ragep, a professor of the history of science at the University of Oklahoma, “could hold a candle to what was going on in the Islamic world until about 1600.” Algebra, algorithm, alchemy, alcohol, alkali, nadir,
zenith, coffee, and lemon: these words all derive from Arabic, reflecting Islam’s contribution to the West.

Today, however, the spirit of science in the Muslim world is as dry as the desert. Pakistani physicist Pervez Amirali Hoodbhoy laid out the grim statistics in a 2007 *Physics Today* article: Muslim countries have nine scientists, engineers, and technicians per thousand people, compared with a world average of forty-one. In these nations, there are approximately 1,800 universities, but only 312 of those universities have scholars who have published journal articles. Of the fifty most-published of these universities, twenty-six are in Turkey, nine are in Iran, three each are in Malaysia and Egypt, Pakistan has two, and Uganda, the U.A.E., Saudi Arabia, Lebanon, Kuwait, Jordan, and Azerbaijan each have one.

There are roughly 1.6 billion Muslims in the world, but only two scientists from Muslim countries have won Nobel Prizes in science (one for physics in 1979, the other for chemistry in 1999). Forty-six Muslim countries combined contribute just 1 percent of the world’s scientific literature; Spain and India each contribute more of the world’s scientific literature than those countries taken together. In fact, although Spain is hardly an intellectual superpower, it translates more books in a single year than the entire Arab world has in the past thousand years. “Though there are talented scientists of Muslim origin working productively in the West,” Nobel laureate physicist Steven Weinberg has observed, “for forty years I have not seen a single paper by a physicist or astronomer working in a Muslim country that was worth reading.”

Comparative metrics on the Arab world tell the same story. Arabs comprise 5 percent of the world’s population, but publish just 1.1 percent of its books, according to the U.N.’s 2003 Arab Human Development Report. Between 1980 and 2000, Korea granted 16,328 patents, while nine Arab countries, including Egypt, Saudi Arabia, and the U.A.E., granted a combined total of only 370, many of them registered by foreigners. A study in 1989 found that in one year, the United States published 10,481 scientific papers that were frequently cited, while the entire Arab world published only four. This may sound like the punch line of a bad joke, but when *Nature* magazine published a sketch of science in the Arab world in 2002, its reporter identified just three scientific areas in which Islamic countries excel: desalination, falconry, and camel reproduction. The recent push to establish new research and science institutions in the Arab world — described in these pages by Waleed Al-Shobakky (see “Petrodollar Science,” Fall 2008) — clearly still has a long way to go.

Given that Arabic science was the most advanced in the world up until about the thirteenth century, it is tempting to ask what went wrong — why it is that modern science did not arise from Baghdad or Cairo or Córdoba. We will turn to this question later, but it is important to keep in mind that the decline of scientific activity is the rule, not the exception, of civilizations. While it is commonplace to assume that the scientific revolution and the progress of technology were inevitable, in fact the West is the single sustained success story out of many civilizations with periods of scientific flourishing.
Like the Muslims, the ancient Chinese and Indian civilizations, both of which were at one time far more advanced than the West, did not produce the scientific revolution.

Nevertheless, while the decline of Arabic civilization is not exceptional, the reasons for it offer insights into the history and nature of Islam and its relationship with modernity. Islam’s decline as an intellectual and political force was gradual but pronounced: while the Golden Age was extraordinarily productive, with the contributions made by Arabic thinkers often original and groundbreaking, the past seven hundred years tell a very different story.

**Why Arabic Science Thrived**

What prompted scientific scholarship to flourish where and when it did? What were the conditions that incubated these important Arabic-speaking scientific thinkers? There is, of course, no single explanation for the development of Arabic science, no single ruler who inaugurated it, no single culture that fueled it. As historian David C. Lindberg puts it in *The Beginnings of Western Science* (1992), Arabic science thrived for as long as it did thanks to “an incredibly complex concatenation of contingent circumstances.”

Scientific activity was reaching a peak when Islam was the dominant civilization in the world. So one important factor in the rise of the scholarly culture of the Golden Age was its material backdrop, provided by the rise of a powerful and prosperous empire. By the year 750, the Arabs had conquered Arabia, Iraq, Syria, Lebanon, Palestine, Egypt, and much of North Africa, Central Asia, Spain, and the fringes of China and India. Newly opened routes connecting India and the Eastern Mediterranean spurred an explosion of wealth through trade, as well as an agricultural revolution.

For the first time since the reign of Alexander the Great, the vast region was united politically and economically. The result was, first, an Arab kingdom under the Umayyad caliphs (ruling in Damascus from 661 to 750) and then an Islamic empire under the Abbasid caliphs (ruling in Baghdad from 751 to 1258), which saw the most intellectually productive age in Arab history. The rise of the first centralized Islamic state under the Abbasids profoundly shaped life in the Islamic world, transforming it from a tribal culture with little literacy to a dynamic empire. To be sure, the vast empire was theologically and ethnically diverse; but the removal of political barriers that previously divided the region meant that scholars from different religious and ethnic backgrounds could travel and interact with each other. Linguistic barriers, too, were decreasingly an issue as Arabic became the common idiom of all scholars across the vast realm.

The spread of empire brought urbanization, commerce, and wealth that helped spur intellectual collaboration. Maarten Bosker of Utrecht University and his colleagues explain that in the year 800, while the Latin West (with the exception of Italy) was “relatively backward,” the Arab world was highly urbanized, with twice the urban population of the West. Several large metropolises — including Baghdad, Basra, Wasit, and Kufa — were unified under the Abbasids; they shared a single spoken language and brisk trade via a network of caravan roads. Baghdad in particular, the Abbasid capital,
was home to palaces, mosques, joint-stock companies, banks, schools, and hospitals; by the tenth century, it was the largest city in the world.

As the Abbasid Empire grew, it also expanded eastward, bringing it into contact with the ancient Egyptian, Greek, Indian, Chinese, and Persian civilizations, the fruits of which it readily enjoyed. (In this era, Muslims found little of interest in the West, and for good reason.) One of the most important discoveries by Muslims was paper, which was probably invented in China around A.D. 105 and brought into the Islamic world starting in the mid-eighth century. The effect of paper on the scholarly culture of Arabic society was enormous: it made the reproduction of books cheap and efficient, and it encouraged scholarship, correspondence, poetry, recordkeeping, and banking.

The arrival of paper also helped improve literacy, which had been encouraged since the dawn of Islam due to the religion’s literary foundation, the Koran. Medieval Muslims took religious scholarship very seriously, and some scientists in the region grew up studying it. Avicenna, for example, is said to have known the entire Koran by heart before he arrived at Baghdad. Might it be fair, then, to say that Islam itself encouraged scientific enterprise? This question provokes wildly divergent answers. Some scholars argue that there are many parts of the Koran and the hadith (the sayings of Muhammad) that exhort believers to think about and try to understand Allah’s creations in a scientific spirit. As one hadith urges, “Seek knowledge, even in China.” But there are other scholars who argue that “knowledge” in the Koranic sense is not scientific knowledge but religious knowledge, and that to conflate such knowledge with modern science is inaccurate and even naïve.

**The Gift of Baghdad**

But the single most significant reason that Arabic science thrived was the absorption and assimilation of the Greek heritage — a development fueled by the translation movement in Abbasid Baghdad. The translation movement, according to Yale historian and classicist Dimitri Gutas, is “equal in significance to, and belongs to the same narrative as ... that of Pericles’ Athens, the Italian Renaissance, or the scientific revolution of the sixteenth and seventeenth centuries.” Whether or not one is willing to grant Gutas the comparison, there is no question that the translation movement in Baghdad — which by the year 1000 saw nearly the entire Greek corpus in medicine, mathematics, and natural philosophy translated into Arabic — provided the foundation for inquiry in the sciences. While most of the great thinkers in the Golden Age were not themselves in Baghdad, the Arabic world’s other cultural centers likely would not have thrived without Baghdad’s translation movement. For this reason, even if it is said that the Golden Age of Arabic science encompasses a large region, as a historical event it especially demands an explanation of the success of Abbasid Baghdad.

The rise to power of the Abbasid caliphate in the year 750 was, as Bernard Lewis put it in *The Arabs in History* (1950), “a revolution in the history of Islam, as important a turning point as the French and Russian revolutions in the history of the West.” Instead of tribe and ethnicity, the Abbasids made religion and language the defining characteristics
of state identity. This allowed for a relatively cosmopolitan society in which all Muslims could participate in cultural and political life. Their empire lasted until 1258, when the Mongols sacked Baghdad and executed the last Abbasid caliph (along with a large part of the Abbasid population). During the years that the Abbasid empire thrived, it deeply influenced politics and society from Tunisia to India.

The Greek-Arabic translation movement in Abbasid Baghdad, like other scholarly efforts elsewhere in the Islamic world, was centered less in educational institutions than in the households of great patrons seeking social prestige. But Baghdad was distinctive: its philosophical and scientific activity enjoyed a high level of cultural support. As Gutas explains in *Greek Thought, Arabic Culture* (1998), the translation movement, which mostly flourished from the middle of the eighth century to the end of the tenth, was a self-perpetuating enterprise supported by “the entire elite of Abbasid society: caliphs and princes, civil servants and military leaders, merchants and bankers, and scholars and scientists; it was not the pet project of any particular group in the furtherance of their restricted agenda.” This was an anomaly in the Islamic world, where for the most part, as Ehsan Masood argues, science was “supported by individual patrons, and when these patrons changed their priorities, or when they died, any institutions that they might have built often died with them.”

There seem to have been three salient factors inspiring the translation movement. First, the Abbasids found scientific Greek texts immensely useful for a sort of technological progress — solving common problems to make daily life easier. The Abbasids did not bother translating works in subjects such as poetry, history, or drama, which they regarded as useless or inferior. Indeed, science under Islam, although in part an extension of Greek science, was much less theoretical than that of the ancients. Translated works in mathematics, for example, were eventually used for engineering and irrigation, as well as in calculation for intricate inheritance laws. And translating Greek works on medicine had obvious practical use.

Astrology was another Greek subject adapted for use in Baghdad: the Abbasids turned to it for proof that the caliphate was the divinely ordained successor to the ancient Mesopotamian empires — although such claims were sometimes eyed warily, because the idea that celestial information can predict the future clashed with Islamic teaching that only God has such knowledge.

There were also practical religious reasons to study Greek science. Mosque timekeepers found it useful to study astronomy and trigonometry to determine the direction to Mecca (*qibla*), the times for prayer, and the beginning of Ramadan. For example, the Arabic astronomer Ibn al-Shatir (died 1375) also served as a religious official, a timekeeper (*muwaqqit*), for the Great Mosque of Damascus. Another religious motivation for translating Greek works was their value for the purposes of rhetoric and what we would today call ideological warfare: Aristotle’s *Topics*, a treatise on logic, was used to aid in religious disputation with non-Muslims and in the conversion of nonbelievers to Islam (which was state policy under the Abbasids).
The second factor central to the rise of the translation movement was that Greek thought had already been diffused in the region, slowly and over a long period, before the Abbasids and indeed before the advent of Islam. Partly for this reason, the Abbasid Baghdad translation movement was not like the West’s subsequent rediscovery of ancient Athens, in that it was in some respects a continuation of Middle Eastern Hellenism. Greek thought spread as early as Alexander the Great’s conquests of Asia and North Africa in the 300s B.C., and Greek centers, such as in Alexandria and the Greco-Bactrian Kingdom (238-140 B.C., in what is now Afghanistan), were productive centers of learning even amid Roman conquest. By the time of the Arab conquests, the Greek tongue was known throughout the vast region, and it was the administrative language of Syria and Egypt. After the arrival of Christianity, Greek thought was spread further by missionary activity, especially by Nestorian Christians. Centuries later, well into the rule of the Abbasids in Baghdad, many of these Nestorians — some of them Arabs and Arabized Persians who eventually converted to Islam — contributed technical skill for the Greek-Arabic translation movement, and even filled many translation-oriented administrative posts in the Abbasid government.

While practical utility and the influence of Hellenism help explain why science could develop, both were true of most of the Arabic world during the Golden Age and so cannot account for the Abbasid translation movement in particular. As Gutas argues, the distinguishing factor that led to that movement was the attempt by the Abbasid rulers to legitimize their rule by co-opting Persian culture, which at the time deeply revered Greek thought. The Baghdad region in which the Abbasids established themselves included a major Persian population, which played an instrumental role in the revolution that ended the previous dynasty; thus, the Abbasids made many symbolic and political gestures to ingratiate themselves with the Persians. In an effort to enfold this constituency into a reliable ruling base, the Abbasids incorporated Zoroastrianism and the imperial ideology of the defunct Persian Sasanian Empire, more than a century gone, into their political platform. The Abbasid rulers sought to establish the idea that they were the successors not to the defeated Arab Umayyads who had been overthrown in 650 but to the region’s previous imperial dynasty, the Sasanians.

This incorporation of Sasanian ideology led to the translation of Greek texts into Arabic because doing so was seen as recovering not just Greek, but Persian knowledge. The Persians believed that sacred ancient Zoroastrian texts were scattered by Alexander the Great’s destruction of Persepolis in 330 B.C., and were subsequently appropriated by the Greeks. By translating ancient Greek texts into Arabic, Persian wisdom could be recovered.

Initially, Arab Muslims themselves did not seem to care much about the translation movement and the study of science, feeling that they had “no ethnic or historical stake in it,” as Gutas explains. This began to change during the reign of al-Mamun (died 833), the seventh Abbasid caliph. For the purposes of opposing the Byzantine Empire, al-Mamun reoriented the translation movement as a means to recovering Greek, rather than Persian, learning. In the eyes of Abbasid Muslims of this era, the ancient Greeks did not have a pristine reputation — they were not Muslims, after all — but at least they were not
tainted with Christianity. The fact that the hated Christian Byzantines did not embrace the ancient Greeks, though, led the Abbasids to warm to them. This philhellenism in the centuries after al-Mamun marked a prideful distinction between the Arabs — who considered themselves “champions of the truth,” as Gutas puts it — and their benighted Christian contemporaries. One Arab philosopher, al-Kindi (died 870), even devised a genealogy that presented Yunan, the ancestor of the ancient Greeks, as the brother of Qahtan, the ancestor of the Arabs.

Until its collapse in the Mongol invasion of 1258, the Abbasid caliphate was the greatest power in the Islamic world and oversaw the most intellectually productive movement in Arab history. The Abbasids read, commented on, translated, and preserved Greek and Persian works that may have been otherwise lost. By making Greek thought accessible, they also formed the foundation of the Arabic Golden Age. Major works of philosophy and science far from Baghdad — in Spain, Egypt, and Central Asia — were influenced by Greek-Arabic translations, both during and after the Abbasids. Indeed, even if it is a matter of conjecture to what extent the rise of science in the West depended on Arabic science, there is no question that the West benefited from both the preservation of Greek works and from original Arabic scholarship that commented on them.

Why the Golden Age Faded
As the Middle Ages progressed, Arabic civilization began to run out of steam. After the twelfth century, Europe had more significant scientific scholars than the Arabic world, as Harvard historian George Sarton noted in his *Introduction to the History of Science* (1927-48). After the fourteenth century, the Arab world saw very few innovations in fields that it had previously dominated, such as optics and medicine; henceforth, its innovations were for the most part not in the realm of metaphysics or science, but were more narrowly practical inventions like vaccines. “The Renaissance, the Reformation, even the scientific revolution and the Enlightenment, passed unnoticed in the Muslim world,” Bernard Lewis remarks in *Islam and the West* (1993).

There was a modest rebirth of science in the Arabic world in the nineteenth century due largely to Napoleon’s 1798 expedition to Egypt, but it was soon followed by decline. Lewis notes in *what went wrong?* That “The relationship between Christendom and Islam in the sciences was now reversed” Those who had been disciples now became teachers; those who had been masters became pupils, often reluctant and resentful pupils.” The civilization that had produced cities, libraries, and observatories and opened itself to the world had now regressed and become closed, resentful, violent, and hostile to discourse and innovation.

What happened? To repeat an important point, scientific decline is hardly peculiar to Arabic-Islamic civilization. Such decline is the norm of history; only in the West did something very different happen. Still, it may be possible to discern some specific causes of decline — and attempting to do so can deepen our understanding of Arabic-Islamic civilization and its tensions with modernity. As Sayyid Jamal al-Din al-Afghani, an influential figure in contemporary pan-Islamism, said in the late nineteenth century, “It is
permissible ... to ask oneself why Arab civilization, after having thrown such a live light on the world, suddenly became extinguished; why this torch has not been relit since; and why the Arab world still remains buried in profound darkness.”

Just as there is no simple explanation for the success of Arabic science, there is no simple explanation for its gradual — not sudden, as al-Afghani claims — demise. The most significant factor was physical and geopolitical. As early as the tenth or eleventh century, the Abbasid Empire began to factionalize and fragment due to increased provincial autonomy and frequent uprisings. By 1258, the little that was left of the Abbasid state was swept away by the Mongol invasion. And in Spain, Christians reconquered Córdoba in 1236 and Seville in 1248. But the Islamic turn away from scholarship actually preceded the civilization’s geopolitical decline — it can be traced back to the rise of the anti-philosophical Ash’arism school among Sunni Muslims, who comprise the vast majority of the Muslim world.

To understand this anti-rationalist movement, we once again turn our gaze back to the time of the Abbasid caliph al-Mamun. Al-Mamun picked up the pro-science torch lit by the second caliph, al-Mansur, and ran with it. He responded to a crisis of legitimacy by attempting to undermine traditionalist religious scholars while actively sponsoring a doctrine called Mu’tazilism that was deeply influenced by Greek rationalism, particularly Aristotelianism. To this end, he imposed an inquisition, under which those who refused to profess their allegiance to Mu’tazilism were punished by flogging, imprisonment, or beheading. But the caliphs who followed al-Mamun upheld the doctrine with less fervor, and within a few decades, adherence to it became a punishable offense. The backlash against Mu’tazilism was tremendously successful: by 885, a half century after al-Mamun’s death, it even became a crime to copy books of philosophy. The beginning of the de-Hellenization of Arabic high culture was underway. By the twelfth or thirteenth century, the influence of Mu’tazilism was nearly completely marginalized.

In its place arose the anti-rationalist Ash’ari school whose increasing dominance is linked to the decline of Arabic science. With the rise of the Ash’arites, the ethos in the Islamic world was increasingly opposed to original scholarship and any scientific inquiry that did not directly aid in religious regulation of private and public life. While the Mu’tazilites had contended that the Koran was created and so God’s purpose for man must be interpreted through reason, the Ash’arites believed the Koran to be coeval with God — and therefore unchallengeable. At the heart of Ash’ari metaphysics is the idea of occasionalism, a doctrine that denies natural causality. Put simply, it suggests natural necessity cannot exist because God’s will is completely free. Ash’arites believed that God is the only cause, so that the world is a series of discrete physical events each willed by God.

As Maimonides described it in The Guide for the Perplexed, this view sees natural things that appear to be permanent as merely following habit. Heat follows fire and hunger follows lack of food as a matter of habit, not necessity, “just as the king generally rides on horseback through the streets of the city, and is never found departing from this habit; but reason does not find it impossible that he should walk on foot through the
place.” According to the occasionalist view, tomorrow coldness might follow fire, and satiety might follow lack of food. God wills every single atomic event and God’s will is not bound up with reason. This amounts to a denial of the coherence and comprehensibility of the natural world. In his controversial 2006 University of Regensburg address, Pope Benedict XVI described this idea by quoting the philosopher Ibn Hazm (died 1064) as saying, “Were it God’s will, we would even have to practice idolatry.” It is not difficult to see how this doctrine could lead to dogma and eventually to the end of free inquiry in science and philosophy.

The greatest and most influential voice of the Ash’arites was the medieval theologian Abu Hamid al-Ghazali (also known as Algazel; died 1111). In his book The Incoherence of the Philosophers, al-Ghazali vigorously attacked philosophy and philosophers — both the Greek philosophers themselves and their followers in the Muslim world (such as al-Farabi and Avicenna). Al-Ghazali was worried that when people become favorably influenced by philosophical arguments, they will also come to trust the philosophers on matters of religion, thus making Muslims less pious. Reason, because it teaches us to discover, question, and innovate, was the enemy; al-Ghazali argued that in assuming necessity in nature, philosophy was incompatible with Islamic teaching, which recognizes that nature is entirely subject to God’s will: “Nothing in nature,” he wrote, “can act spontaneously and apart from God.” While al-Ghazali did defend logic, he did so only to the extent that it could be used to ask theological questions and wielded as a tool to undermine philosophy. Sunnis embraced al-Ghazali as the winner of the debate with the Hellenistic rationalists, and opposition to philosophy gradually ossified, even to the extent that independent inquiry became a tainted enterprise, sometimes to the point of criminality. It is an exaggeration to say, as Steven Weinberg claimed in the Times of London, that after al-Ghazali “there was no more science worth mentioning in Islamic countries”; in some places, especially Central Asia, Arabic work in science continued for some time, and philosophy was still studied somewhat under Shi’ite rule. (In the Sunni world, philosophy turned into mysticism.) But the fact is, Arab contributions to science became increasingly sporadic as the anti-rationalism sank in.

The Ash’ari view has endured to this day. Its most extreme form can be seen in some sects of Islamists. For example, Mohammed Yusuf, the late leader of a group called the Nigerian Talibin, explained why “Western education is a sin” by explaining its view on rain: “We believe it is a creation of God rather than an evaporation caused by the sun that condenses and becomes rain.” The Ash’ari view is also evident when Islamic leaders attribute natural disasters to God’s vengeance, as they did when they said that the 2010 eruption of Iceland’s Eyjafjallajökull volcano was the result of God’s anger at immodestly dressed women in Europe. Such inferences sound crazy to Western ears, but given their frequency in the Muslim world, they must sound at least a little less crazy to Muslims. As Robert R. Reilly argues in The Closing of the Muslim Mind (2010), “the fatal disconnect between the creator and the mind of his creature is the source of Sunni Islam’s most profound woes.”
A similar ossification occurred in the realm of law. The first four centuries of Islam saw vigorous discussion and flexibility regarding legal issues; this was the tradition of *ijtihad*, or independent judgment and critical thinking. But by the end of the eleventh century, discordant ideas were increasingly seen as a problem, and autocratic rulers worried about dissent — so the “gates of *ijtihad*” were closed for Sunni Muslims: *ijtihad* was seen as no longer necessary, since all important legal questions were regarded as already answered. New readings of Islamic revelation became a crime. All that was left to do was to submit to the instructions of religious authorities; to understand morality, one needed only to read legal decrees. Thinkers who resisted the closing came to be seen as nefarious dissidents. (Averroës, for example, was banished for heresy and his books were burned.)

**Why Inquiry Failed in the Islamic World**

But is Ash’arism the deepest root of Arabic science’s demise? That the Ash’arites won and the Mu’tazilites lost suggests that for whatever reason, Muslims already found Ash’ari thought more convincing or more palatable; it suited prevailing sentiments and political ideas. Indeed, Muslim theologians appeared receptive to the occasionalist view as early as the ninth century, before the founder of Ash’arism was even born. Thus the Ash’ari victory raises thorny questions about the theological-political predispositions of Islam.

As a way of articulating questions that lie deeper than the Ash’arism-Mu’tazilism debate, it is helpful to briefly compare Islam with Christianity. Christianity acknowledges a private-public distinction and (theoretically, at least) allows adherents the liberty to decide much about their social and political lives. Islam, on the other hand, denies any private-public distinction and includes laws regulating the minutest details of private life. Put another way, Islam does not acknowledge any difference between religious and political ends: it is a religion that specifies political rules for the community.

Such differences between the two faiths can be traced to the differences between their prophets. While Christ was an outsider of the state who ruled no one, and while Christianity did not become a state religion until centuries after Christ’s birth, Mohammed was not only a prophet but also a chief magistrate, a political leader who conquered and governed a religious community he founded. Because Islam was born outside of the Roman Empire, it was never subordinate to politics. As Bernard Lewis puts it, Mohammed was his own Constantine. This means that, for Islam, religion and politics were interdependent from the beginning: Islam needs a state to enforce its laws, and the state needs a basis in Islam to be legitimate. To what extent, then, do Islam’s political proclivities make free inquiry — which is inherently subversive to established rules and customs — possible at a deep and enduring institutional level?

Some clues can be found by comparing institutions in the medieval period. Far from accepting anything close to the occasionalism and legal positivism of the Sunnis, European scholars argued explicitly that when the Bible contradicts the natural world, the holy book should not be taken literally. Influential philosophers like Augustine held that knowledge and reason precede Christianity; he approached the subject of scientific inquiry with cautious encouragement, exhorting Christians to use the classical sciences as
a handmaiden of Christian thought. Galileo’s house arrest notwithstanding, his famous remark that “the intention of the Holy Ghost is to teach us how one goes to heaven, not how heaven goes” underscores the durability of the scientific spirit among pious Western societies. Indeed, as David C. Lindberg argues in an essay collected in *Galileo Goes to Jail and Other Myths about Science and Religion* (2009), “No institution or cultural force of the patristic period offered more encouragement for the investigation of nature than did the Christian church.” And, as Baylor University sociologist Rodney Stark notes in his book *For the Glory of God* (2003), many of the greatest scientists of the scientific revolution were also Christian priests or ministers.

The Church’s acceptance and even encouragement of philosophy and science was evident from the High Middle Ages to modern times. As the late Ernest L. Fortin of Boston College noted in an essay collected in *Classical Christianity and the Political Order* (1996), unlike al-Farabi and his successors, “Aquinas was rarely forced to contend with an anti-philosophic bias on the part of the ecclesiastical authorities. As a Christian, he could simply assume philosophy without becoming publicly involved in any argument for or against it.” And when someone like Galileo got in trouble, his work moved forward and his inquiry was carried on by others; in other words, institutional dedication to scientific inquiry was too entrenched in Europe for any authority to control. After about the middle of the thirteenth century in the Latin West, we know of no instance of persecution of anyone who advocated philosophy as an aid in interpreting revelation. In this period, “attacks on reason would have been regarded as bizarre and unacceptable,” explains historian Edward Grant in *Science and Religion, 400 B.C. to A.D. 1550*.

The success of the West is a topic that could fill — indeed, has filled — many large books. But some general comparisons are helpful in understanding why Islam was so institutionally different from the West. The most striking difference is articulated by Bassam Tibi in *The Challenge of Fundamentalism* (1998): “because rational disciplines had not been institutionalized in classical Islam, the adoption of the Greek legacy had no lasting effect on Islamic civilization.” In *The Rise of Early Modern Science*, Toby E. Huff makes a persuasive argument for why modern science emerged in the West and not in Islamic (or Chinese) civilization:

The rise of modern science is the result of the development of a civilizationally based culture that was uniquely humanistic in the sense that it tolerated, indeed, protected and promoted those heretical and innovative ideas that ran counter to accepted religious and theological teaching. Conversely, one might say that critical elements of the scientific worldview were surreptitiously encoded in the religious and legal presuppositions of the European West.

In other words, Islamic civilization did not have a culture hospitable to the advancement of science, while medieval Europe did.

The contrast is most obvious in the realm of formal education. As Huff argues, the lack of a scientific curriculum in medieval madrassas reflects a deeper absence of a capacity or
The exclusion of science and mathematics from the madrassas suggests that these subjects “were institutionally marginal in medieval Islamic life,” writes Huff. Such inquiry was tolerated, and sometimes promoted by individuals, but it was never “officially institutionalized and sanctioned by the intellectual elite of Islam.” This meant that when intellectual discoveries were made, they were not picked up and carried by students, and did not influence later thinkers in Muslim communities. No one paid much attention to the work of Averroës after he was driven out of Spain to Morocco, for instance — that is, until Europeans rediscovered his work. Perhaps the lack of institutional support for science allowed Arabic thinkers (such as al-Farabi) to be bolder than their European counterparts. But it also meant that many Arabic thinkers relied on the patronage of friendly rulers and ephemeral conditions.

By way of contrast, the legal system that developed in twelfth- and thirteenth-century Europe — which saw the absorption of Greek philosophy, Roman law, and Christian theology — was instrumental in forming a philosophically and theologically open culture that respected scientific development. As Huff argues, because European universities were legally autonomous, they could develop their own rules, scholarly norms, and curricula. The norms they incorporated were those of curiosity and skepticism, and the curricula they chose were steeped in ancient Greek philosophy. In the medieval Western world, a spirit of skepticism and inquisitiveness moved theologians and philosophers. It was a spirit of “probing and poking around,” as Edward Grant writes in *God and Reason in the Middle Ages* (2001).

It was this attitude of inquiry that helped lay the foundation for modern science. Beginning in the early Middle Ages, this attitude was evident in technological innovations among even unlearned artisans and merchants. These obscure people contributed to the development of practical technologies, such as the mechanical clock (circa 1272) and spectacles (circa 1284). Even as early as the sixth century, Europeans...
strove to invent labor-saving technology, such as the heavy-wheeled plow and, later, the padded horse collar. According to research by the late Charles Issawi of Princeton University, eleventh-century England had more mills per capita than even the Ottoman lands at the height of the empire’s power. And although it was in use since 1460 in the West, the printing press was not introduced in the Islamic world until 1727. The Arabic world appears to have been even slower in finding uses for academic technological devices. For instance, the telescope appeared in the Middle East soon after its invention in 1608, but it failed to attract excitement or interest until centuries later.

As science in the Arabic world declined and retrogressed, Europe hungrily absorbed and translated classical and scientific works, mainly through cultural centers in Spain. By 1200, Oxford and Paris had curricula that included works of Arabic science. Works by Aristotle, Euclid, Ptolemy, and Galen, along with commentaries by Avicenna and Averroës, were all translated into Latin. Not only were these works taught openly, but they were formally incorporated into the program of study of universities. Meanwhile, in the Islamic world, the dissolution of the Golden Age was well underway.

A Gold Standard
In trying to explain the Islamic world’s intellectual laggardness, it is tempting to point to the obvious factors: authoritarianism, bad education, and underfunding (Muslim states spend significantly less than developed states on research and development as a percentage of GDP). But these reasons are all broad and somewhat crude, and raise more questions than answers. At a deeper level, Islam lags because it failed to offer a way to institutionalize free inquiry. That, in turn, is attributable to its failure to reconcile faith and reason. In this respect, Islamic societies have fared worse not just than the West but also than many societies of Asia. With a couple of exceptions, every country in the Middle Eastern parts of the Muslim world has been ruled by an autocrat, a radical Islamic sect, or a tribal chieftain. Islam has no tradition of separating politics and religion.

The decline of Islam and the rise of Christianity was a development that was and remains deeply humiliating for Muslims. Since Islam tended to ascribe its political power to its theological superiority over other faiths, its fading as a worldly power raised profound questions about where a wrong turn was made. Over at least the past century, Muslim reformers have been debating how best to reacquire the lost honor. In the same period, the Muslim world tried, and failed, to reverse its decline by borrowing Western technology and sociopolitical ideas, including secularization and nationalism. But these tastes of “modernization” turned many Muslims away from modernity. This raises a question: Can and should Islam’s past achievements serve as a standard for Islam’s future? After all, it is quite common to imply, as President Obama did, that knowledge of the Golden Age of Arabic science will somehow exhort the Islamic world to improve itself and to hate the West less.

The story of Arabic science offers a window into the relationship between Islam and modernity; perhaps, too, it holds out the prospect of Islam coming to benefit from principles it badly needs in order to prosper, such as sexual equality, the rule of law, and
free civil life. But the predominant posture among many Muslims today is that the good life is best approximated by returning to a pristine and pious past — and this posture has proven poisonous to coping with modernity. Islamism, the cause of violence that the world is now agonizingly familiar with, arises from doctrines characterized by a deep nostalgia for the Islamic classical period. Even today, suggesting that the Quran isn’t coeternal with God can make one an infidel.

And yet intellectual progress and cultural openness were once encouraged among many Arabic societies. So to the extent that appeals to the salutary classical attitude can be found in the Islamic tradition, the fanatical false nostalgia might be tamed. Some reformers already point out that many medieval Muslims embraced reason and other ideas that presaged modernity, and that doing so is not impious and does not mean simply giving up eternal rewards for materialistic ones. On an intellectual level, this effort could be deepened by challenging the Ash’ari orthodoxy that has dominated Sunni Islam for a thousand years — that is, by asking whether al-Ghazali and his Ash’arite followers really understood nature, theology, and philosophy better than the Mu’tazilites.

But there are reasons why exhortation to emulate Muslim ancestors may also be misguided. One is that medieval Islam does not offer a decent political standard. When compared to modern Western standards, the Golden Age of Arabic science was decidedly not a Golden Age of equality. While Islam was comparatively tolerant at the time of members of other religions, the kind of tolerance we think of today was never a virtue for early Muslims (or early Christians, for that matter). As Bernard Lewis puts it in The Jews of Islam (1984), giving equal treatment to followers and rejecters of the true faith would have been seen not only as an absurdity but also an outright “dereliction of duty.” Jews and Christians were subjected to official second-class sociopolitical status beginning in Mohammed’s time, and Abbasid-era oppressions also included religious persecution and the eradication of churches and synagogues. The Golden Age was also an era of widespread slavery of persons deemed to be of even lower class. For all the estimable achievements of the medieval Arabic world, it is quite clear that its political and social history should not be made into a celebrated standard.

There is a more fundamental reason, however, why it may not make much sense to urge the Muslim world to restore those parts of its past that valued rational and open inquiry: namely, a return to the Mu’tazilites may not be enough. Even the most rationalist schools in Islam did not categorically argue for the primacy of reason. As Ali A. Allawi argues in The Crisis of Islamic Civilization (2009), “None of the free-thinking schools in classical Islam — such as the Mu’tazila — could ever entertain the idea of breaking the God-Man relationship and the validity of revelation, in spite of their espousal of a rationalist philosophy.” Indeed, in 1889 the Hungarian scholar Ignaz Goldziher noted in his essay “The Attitude of Orthodox Islam Toward the ‘Ancient Sciences’” that it was not only Ash’arite but Mu’tazilite circles that “produced numerous polemical treatises against Aristotelian philosophy in general and against logic in particular.” Even before al-Ghazali’s attack on the Mu’tazilites, engaging in Greek philosophy was not exactly a safe task outside of auspicious but rather ephemeral conditions.
But more importantly, merely popularizing previous rationalist schools would not go very far in persuading Muslims to reflect on the theological-political problem of Islam. For all the great help that the rediscovery of the influential Arabic philosophers (especially al-Farabi, Averroës, and Maimonides) would provide, no science-friendly Islamic tradition goes nearly far enough, to the point that it offers a theological renovation in the vein of Luther and Calvin — a reinterpretation of Islam that challenges the faith’s comprehensive ruling principles in a way that simultaneously convinces Muslims that they are in fact returning to the fundamentals of their faith.

There is a final reason why it makes little sense to exhort Muslims to their own past: while there are many things that the Islamic world lacks, pride in heritage is not one of them. What is needed in Islam is less self-pride and more self-criticism. Today, self-criticism in Islam is valued only insofar as it is made as an appeal to be more pious and less spiritually corrupt. And yet most criticism in the Muslim world is directed outward, at the West. This prejudice — what Fouad Ajami has called (referring to the Arab world) “a political tradition of belligerent self-pity” — is undoubtedly one of Islam’s biggest obstacles. It makes information that contradicts orthodox belief irrelevant, and it closes off debate about the nature and history of Islam.

In this respect, inquiry into the history of Arabic science, and the recovery and research of manuscripts of the era, may have a beneficial effect — so long as it is pursued in an analytical spirit. That would mean that Muslims would use it as a resource within their own tradition to critically engage with their philosophical, political, and founding flaws. If that occurs, it will not arise from any Western outreach efforts, but will be a consequence of Muslims’ own determination, creativity, and wisdom — in short, those very traits that Westerners rightly ascribe to the Muslims of the Golden Age.

2.4. Original Contributions of Arabic Science in the Muslim World

A preliminary caution must be noted about both parts of the term “Arabic science.” This is, first, because the scientists discussed here were not all Arab Muslims. Indeed, most of the greatest thinkers of the era were not ethnically Arab. This is not surprising considering that, for several centuries throughout the Middle East, Muslims were a minority (a trend that only began to change at the end of the tenth century). The second caution about “Arabic science” is that it was not science as we are familiar with it today. Pre-modern science, while not blind to utility, sought knowledge primarily in order to understand philosophical questions concerned with meaning, being, the good, and so on. Modern science, by contrast, grew out of a revolution in thought that reoriented politics around individual comfort through the mastery of nature. Modern science dismisses ancient metaphysical questions as (to borrow Francis Bacon’s words) the pursuit of pleasure and vanity. Whatever modern science owes to Arabic science, the intellectual activity of the medieval Islamic world was not of the same kind as the European scientific revolution, which came after a radical break from ancient natural philosophy. Indeed, even though we use the term “science” for convenience, it is important to remember that this word was not coined until the nineteenth century; the closest word in Arabic — ilm — means “knowledge,” and not necessarily that of the natural world.
Still, there are two reasons why it makes sense to refer to scientific activity of the Golden Age as Arabic. The first is that most of the philosophical and scientific work at the time was eventually translated into Arabic, which became the language of most scholars in the region, regardless of ethnicity or religious background. And second, the alternatives — “Middle Eastern science” or “Islamic science” — are even less accurate. This is in part because very little is known about the personal backgrounds of these thinkers. But it is also because of another caution we must keep in mind about this subject, which ought to be footnoted to every broad assertion made about the Golden Age: surprisingly little is known for certain even about the social and historical context of this era. Abdelhamid I. Sabra, a now-retired professor of the history of Arabic science who taught at Harvard, described his field to the New York Times in 2001 as one that “hasn’t even begun yet.”

That said, the field has advanced far enough to convincingly demonstrate that Arabic civilization contributed much more to the development of science than the passive transmission to the West of ancient thought and of inventions originating elsewhere (such as the numeral system from India and papermaking from China). For one thing, the scholarly revival in Abbasid Baghdad (751-1258) that resulted in the translation of almost all the scientific works of the classical Greeks into Arabic is nothing to scoff at. But beyond their translations of (and commentaries upon) the ancients, Arabic thinkers made original contributions, both through writing and methodical experimentation, in such fields as philosophy, astronomy, medicine, chemistry, geography, physics, optics, and mathematics.

Perhaps the most oft-repeated claim about the Golden Age is that Muslims invented algebra. This claim is largely true: initially inspired by Greek and Indian works, the Persian al-Khwarizmi (died 850) wrote a book from whose title we get the term algebra. The book starts out with a mathematical introduction, and proceeds to explain how to solve then-commonplace issues involving trade, inheritance, marriage, and slave emancipations. (Its methods involve no equations or algebraic symbols, instead using geometrical figures to solve problems that today would be solved using algebra.) Despite its grounding in practical affairs, this book is the primary source that contributed to the development of the algebraic system that we know today.

The Golden Age also saw advances in medicine. One of the most famous thinkers in the history of Arabic science, and considered among the greatest of all medieval physicians, was Rhazes (also known as al-Razi). Born in present-day Tehran, Rhazes (died 925) was trained in Baghdad and became the director of two hospitals. He identified smallpox and measles, writing a treatise on them that became influential beyond the Middle East and into nineteenth-century Europe. Rhazes was the first to discover that fever is a defense mechanism. And he was the author of an encyclopedia of medicine that spanned twenty-three volumes. What is most striking about his career, as Ehsan Masood points out in Science and Islam, is that Rhazes was the first to seriously challenge the seeming infallibility of the classical physician Galen. For example, he disputed Galen’s theory of humors, and he conducted a controlled experiment to see if bloodletting, which was the
most common medical procedure up until the nineteenth century, actually worked as a medical treatment. (He found that it did.) Rhazes provides a clear instance of a thinker explicitly questioning, and empirically testing, the widely-accepted theories of an ancient giant, while making original contributions to a field.

Breakthroughs in medicine continued with the physician and philosopher Avicenna (also known as Ibn-Sina; died 1037), whom some consider the most important physician since Hippocrates. He authored the *Canon of Medicine*, a multi-volume medical survey that became the authoritative reference book for doctors in the region, and — once translated into Latin — a staple in the West for six centuries. The *Canon* is a compilation of medical knowledge and a manual for drug testing, but it also includes Avicenna’s own discoveries, including the infectiousness of tuberculosis.

Like the later European Renaissance, the Arabic Golden Age also had many polymaths who excelled in and advanced numerous fields. One of the earliest such polymaths was al-Farabi (also known as Alpharabius, died ca. 950), a Baghdadi thinker who, in addition to his prolific writing on many aspects of Platonic and Aristotelian philosophy, also wrote on physics, psychology, alchemy, cosmology, music, and much else. So esteemed was he that he came to be known as the “Second Teacher” — second greatest, that is, after Aristotle. Another great polymath was al-Biruni (died 1048), who wrote 146 treatises totaling 13,000 pages in virtually every scientific field. His major work, *The Description of India*, was an anthropological work on Hindus. One of al-Biruni’s most notable accomplishments was the near-accurate measurement of the Earth’s circumference using his own trigonometric method; he missed the correct measurement of 24,900 miles by only 200 miles. (However, unlike Rhazes, Avicenna, and al-Farabi, al-Biruni’s works were never translated into Latin and thus did not have much influence beyond the Arabic world.) Another of the most brilliant minds of the Golden Age was the physicist and geometrician Alhazen (also known as Ibn al-Haytham; died 1040). Although his greatest legacy is in optics — he showed the flaws in the theory of extramission, which held that our eyes emit energy that makes it possible for us to see — he also did work in astronomy, mathematics, and engineering. And perhaps the most renowned scholar of the late Golden Age was Averroës (also known as Ibn Rushd; died 1198), a philosopher, theologian, physician, and jurist best known for his commentaries on Aristotle. The 20,000 pages he wrote over his lifetime included works in philosophy, medicine, biology, physics, and astronomy.
PHILOSOPHICAL FOUNDATIONS OF SCIENCE-I

Written by: Dr. Hafiz Muhammad Ather Khan
Reviewed by: Dr. Saira
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INTRODUCTION

Philosophy of science is a branch of philosophy concerned with the foundations, methods, and implications of science. The central questions of this study concern what qualifies as science, the reliability of scientific theories, and the ultimate purpose of science. This discipline overlaps with metaphysics, ontology, and epistemology, for example, when it explores the relationship between science and truth.

There is no consensus among philosophers about many of the central problems concerned with the philosophy of science, including whether science can reveal the truth about unobservable things and whether scientific reasoning can be justified at all. In addition to these general questions about science as a whole, philosophers of science consider problems that apply to particular sciences (such as biology or physics). Some philosophers of science also use contemporary results in science to reach conclusions about philosophy itself.

While philosophical thought pertaining to science dates back at least to the time of Aristotle, philosophy of science emerged as a distinct discipline only in the middle of the 20th century in the wake of the logical positivism movement, which aimed to formulate criteria for ensuring all philosophical statements' meaningfulness and objectively assessing them. Thomas Kuhn's landmark 1962 book *The Structure of Scientific Revolutions* was also formative, challenging the view of scientific progress as steady, cumulative acquisition of knowledge based on a fixed method of systematic experimentation and instead arguing that any progress is relative to a "paradigm," the set of questions, concepts, and practices that define a scientific discipline in a particular historical period. Karl Popper and Charles Sanders Pierce moved on from positivism to establish a modern set of standards for scientific methodology. Distinguishing between science and non-science is referred to as the demarcation problem. For example, should psychoanalysis be considered science? How about so-called creation science, the inflationary multiverse hypothesis, or macroeconomics? Karl Popper called this the central question in the philosophy of science. However, no unified account of the problem has won acceptance among philosophers, and some regard the problem as unsolvable or uninteresting. Martin Gardner has argued for the use of a Potter Stewart standard ("I know it when I see it") for recognizing pseudoscience.

Early attempts by the logical positivists grounded science in observation while non-science was non-observational and hence meaningless. Popper argued that the central property of science is falsifiability. That is, every genuinely scientific claim is capable of being proven false, at least in principle. An area of study or speculation that masquerades as science in an attempt to claim a legitimacy that it would not otherwise be able to achieve is referred to as pseudoscience, fringe science, or junk science.
Physicist Richard Feynman coined the term "cargo cult science" for cases in which researchers believe they are doing science because their activities have the outward appearance of it but actually lack the "kind of utter honesty" that allows their results to be rigorously evaluated.

**OBJECTIVES**

After reading this Unit you will be able to:
1. know the concept of philosophy and science.
2. understand the similarities and differences between science and technology.
3.1. Philosophy of Science
IT is a branch of philosophy concerned with the foundations, methods, and implications of science. The central questions of this study concern what qualifies as science, the reliability of scientific theories, and the ultimate purpose of science. This discipline overlaps with metaphysics, ontology, and epistemology, for example, when it explores the relationship between science and truth.

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Subsequently, the coherentist approach to science, in which a theory is validated if it makes sense of observations as part of a coherent whole, became prominent due to W. V. Quine and others. Some thinkers such as Stephen Jay Gould seek to ground science in axiomatic assumptions, such as the uniformity of nature. A vocal minority of philosophers, and Paul Feyerabend (1924–1994) in particular, argue that there is no such thing as the "scientific method", so all approaches to science should be allowed, including explicitly supernatural ones. Another approach to thinking about science involves studying how knowledge is created from a sociological perspective, an approach represented by scholars like David Bloor and Barry Barnes. Finally, a tradition in continental philosophy approaches science from the perspective of a rigorous analysis of human experience.

Philosophies of the particular sciences range from questions about the nature of time raised by Einstein's general relativity, to the implications of economics for public policy. A central theme is whether one scientific discipline can be reduced to the terms of another. That is, can chemistry be reduced to physics, or can sociology be reduced to individual psychology? The general questions of philosophy of science also arise with greater specificity in some particular sciences. For instance, the question of the validity of scientific reasoning is seen
in a different guise in the foundations of statistics. The question of what counts as science and what should be excluded arises as a life-or-death matter in the philosophy of medicine. Additionally, the philosophies of biology, of psychology, and of the social sciences explore whether the scientific studies of human nature can achieve objectivity or are inevitably shaped by values and by social relations.

3.2. Similarities and Differences between Science and Technology

The words *science* and *technology* can and often are used interchangeably. But the goal of *science* is the pursuit of knowledge for its own sake while the goal of *technology* is to create products that solve problems and improve human life. Simply put, *technology* is the practical application of *science*.

**Comparison Chart**

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<thead>
<tr>
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<th>Science</th>
<th>Technology</th>
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<tr>
<td><strong>Motto</strong></td>
<td>Science is knowing.</td>
<td>Technology is doing</td>
</tr>
<tr>
<td><strong>Mission</strong></td>
<td>The search for and theorizing about cause</td>
<td>The search for and theorizing about new processes.</td>
</tr>
<tr>
<td><strong>Result Relevance</strong></td>
<td>Making virtually value-free statements</td>
<td>Activities always value-laden</td>
</tr>
<tr>
<td><strong>Evaluation Methods</strong></td>
<td>Analysis, generalization and creation of theories</td>
<td>Analysis and synthesis of design</td>
</tr>
<tr>
<td><strong>Goals achieved through</strong></td>
<td>Corresponding Scientific Processes</td>
<td>Key Technological Processes</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td>Focuses on understanding natural phenomena</td>
<td>focuses on understanding the made environment</td>
</tr>
<tr>
<td><strong>Development Methods</strong></td>
<td>Discovery (controlled by experimentation)</td>
<td>Design, invention, production</td>
</tr>
<tr>
<td><strong>Most observed quality</strong></td>
<td>Drawing correct conclusions based on good theories and accurate data</td>
<td>Taking good decisions based on incomplete data and approximate models</td>
</tr>
<tr>
<td><strong>Skills needed to excel</strong></td>
<td>Experimental and logical skills</td>
<td>Design, construction, testing, planning, quality assurance, problem solving, decision making, interpersonal and communication skills</td>
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Definition of Science and Technology

Science from the Latin scientia (knowledge) is a system of acquiring knowledge based on the scientific method, as well as the organized body of knowledge gained through such research. Science as defined here is sometimes termed pure science to differentiate it from applied science, which is the application of scientific research to specific human needs.

Technology is a broad concept that deals with a species' usage and knowledge of tools and crafts, and how it affects a species' ability to control and adapt to its environment. In human society, it is a consequence of science and engineering, although several technological advances predate the two concepts. Science refers to a system of acquiring knowledge. This system uses observation and experimentation to describe and explain natural phenomena. The term science also refers to the organized body of knowledge people have gained using that system.

Fields of science are commonly classified along two major lines:
1. Natural sciences, which study natural phenomena (including biological life),
2. Social sciences, which study human behavior and societies.

These groupings are empirical sciences, which means the knowledge must be based on observable phenomena and capable of being tested for its validity by other researchers working under the same conditions.

Differences in Etymology

The word science comes through the Old French, and is derived from the Latin word scientia for knowledge, which in turn comes from scio - 'I know'. From the Middle Ages to the Enlightenment, science or scientia meant any systematic recorded knowledge. Science therefore had the same sort of very broad meaning that philosophy had at that time. In other languages, including French, Spanish, Portuguese, and Italian, the word corresponding to science also carries this meaning. Today, the primary meaning of "science" is generally limited to empirical study involving use of the scientific method.

Technology is a term with origins in the Greek "technologia", "τεχνολογία" - "teche", "τέχνη" ("craft") and "logia", "λογία" ("saying"). However, a strict definition is elusive; "technology" can refer to material objects of use to humanity, such as machines, hardware or utensils, but can also encompass broader themes, including systems, methods of organization, and techniques. The term can either be applied generally or to specific areas: examples include "construction technology", "medical technology", or "state-of-the-art technology".

Is Technology Related to Science?

Bigelow's phrase[1] "the practical applications of science" points to the root of much of the current confusion as to the meaning of technology. In using this phrase to describe technology he effectively placed technology beneath the umbrella of science to such an extent that science and technology are now, as Rose described, seen by many as an
"indivisible pair" with technology as the subservient and dependant partner. Thus, for much of the time the pair are wrapped together into a single conceptual package known simply as "science". This point is emphasised when surfing the Internet for technology-related teaching resources. A plethora of lesson plans exist at sites dedicated to science education. The problem is, though, that many of these lessons should properly be termed "technology" but are all too often referred to as "Applied Science".

One source of confusion is the undoubted relationship that exists between science and technology and Sparks pointed out that even though science and technology overlap in an area which might be referred to as "applied science", there are a number of important differences between the two, even though these differences might not be self-evident to an average member of the general public who, through neglect and through repeated use of the phrase "science and technology" has lost the distinction between "science" and between "technology". The two cannot be told apart, which is hardly surprising given that, as Mayr put it: "... practical usable criteria for making sharp neat distinctions between science and technology do not exist."

Science vs Technology
When you hear the term science, it is typically associated with the term technology "especially when the two are talked about as subjects in school. Although these two terms are often interchanged, there is actually a sparse difference between the two. Perhaps the best way to differentiate science and technology, is to have a quick definition of each term. Science is a systematic knowledge base, where a series of steps is followed in order to reliably predict the type of outcome. It can be broadly defined as the study of things with branches like biology, chemistry, physics and psychology.

Technology, on the other hand, is more of an applied science. It is where tools and knowledge are used for the study of a particular science. For example, the science of energy can have technology as its application. In the case of energy as a subject in science, solar panels can be used for a variety of technologies, an example of which are solar-powered lights.

If the goal of science is the pursuit of knowledge for science’s sake, technology aims to create systems to meet the needs of people. Science has a quest of explaining something, while technology is leaning more towards developing a use for something.

Science focuses more on analysis, generalizations and the creation of theories “” while with technology, it focuses more on analysis and synthesis of design. Science is controlled by experimentation, while technology also involves design, invention and production. If science is all about theories, technology is all about processes. Finally, in order for you to excel in science, you need to have experimental and logical skills. Meanwhile, technology requires a myriad of skills including design, construction, testing, quality assurance and problem-solving.
3.3. **Inductive Reasoning Vs Deductive Reasoning**

This is because *inductive reasoning* starts with a conclusion and *deductive reasoning* starts with a premise... Therefore, *inductive reasoning* moves from specific instances into a generalized conclusion, while *deductive reasoning* moves from generalized principles that are known to be true to a true and specific conclusion.

**Inductive reasoning**

Inductive reasoning is the opposite of deductive reasoning. Inductive reasoning makes broad generalizations from specific observations. "In inductive inference, we go from the specific to the general. We make many observations, discern a pattern, make a generalization, and infer an explanation or a theory," Wassertheil-Smoller told Live Science. "In science there is a constant interplay between inductive inference (based on observations) and deductive inference (based on theory), until we get closer and closer to the 'truth,' which we can only approach but not ascertain with complete certainty."

Even if all of the premises are true in a statement, inductive reasoning allows for the conclusion to be false. Here’s an example: "Harold is a grandfather. Harold is bald. Therefore, all grandfathers are bald." The conclusion does not follow logically from the statements. Inductive reasoning has its place in the scientific method. Scientists use it to form hypotheses and theories. Deductive reasoning allows them to apply the theories to specific situations.

**Abductive Reasoning**

Another form of scientific reasoning that doesn't fit in with inductive or deductive reasoning is abductive. Abductive reasoning usually starts with an incomplete set of observations and proceeds to the likeliest possible explanation for the group of observations, according to Butte College. It is based on making and testing hypotheses using the best information available. It often entails making an educated guess after observing a phenomenon for which there is no clear explanation. Abductive reasoning is useful for forming hypotheses to be tested. Abductive reasoning is often used by doctors who make a diagnosis based on test results and by jurors who make decisions based on the evidence presented to them.

3.4. **Empiricism**

The theory that all knowledge is based on experience derived from the senses. Stimulated by the rise of experimental science, it developed in the 17th and 18th centuries, expounded in particular by John Locke, George Berkeley, and David Hume.

Empiricism is a theory that states that knowledge comes only or primarily from sensory experience.[1] One of several views of epistemology, the study of human knowledge, along with rationalism and skepticism, empiricism emphasizes the role of empirical evidence in the formation of ideas, over the notion of innate ideas or traditions.[2] Empiricists may argue however that traditions (or customs) arise due to relations of previous sense experiences.[3]
Empiricism in the philosophy of science emphasizes evidence, especially as discovered in experiments. It is a fundamental part of the scientific method that all hypotheses and theories must be tested against observations of the natural world rather than resting solely on a priori reasoning, intuition, or revelation.

Empiricism, often used by natural scientists, says that "knowledge is based on experience" and that "knowledge is tentative and probabilistic, subject to continued revision and falsification."[4] One of the epistemological tenets is that sensory experience creates knowledge. Empirical research, including experiments and validated measurement tools, guides the scientific method. Empiricism is the theory that the origin of all knowledge is sense experience. It emphasizes the role of experience and evidence, especially sensory perception, in the formation of ideas, and argues that the only knowledge humans can have is a posteriori (i.e. based on experience). Most empiricists also discount the notion of innate ideas or innatism (the idea that the mind is born with ideas or knowledge and is not a "blank slate" at birth). In order to build a more complex body of knowledge from these direct observations, induction or inductive reasoning (making generalizations based on individual instances) must be used. This kind of knowledge is therefore also known as indirect empirical knowledge. Empiricism is contrasted with Rationalism, the theory that the mind may apprehend some truths directly, without requiring the medium of the senses.

The term "empiricism" has a dual etymology, stemming both from the Greek word for "experience" and from the more specific classical Greek and Roman usage of "empiric", referring to a physician whose skill derives from practical experience as opposed to instruction in theory (this was its first usage). The term "empirical" (rather than "empiricism") also refers to the method of observation and experiment used in the natural and social sciences. It is a fundamental requirement of the scientific method that all hypotheses and theories must be tested against observations of the natural world, rather than resting solely on a priori reasoning, intuition or revelation. Hence, science is considered to be methodologically empirical in nature.

3.5. Constructivist Empiricism and Science Education
The controversy between social constructivists and scientific realists both in the philosophy of science and in science education shows no sign of abating. For many participants in this controversy Social Constructivism and Scientific Realism seem like the only two alternatives. Fortunately, this is not so. I would like to present a compromise position: the theory of Bas van Fraassen, which he calls Constructive Empiricism.[1] I will suggest that this theory avoids many of the problems that plague Scientific Realism and Social Constructivism in relation to the philosophy of science. Its implications for science education have not to my knowledge been spelled out. Here I will suggest some implications that should be congenial to both social constructivists and its critics.
Constructive Empiricism
Van Fraassen believes that the primary criterion for judging a scientific theory is whether it is empirically adequate; that is, whether it accounts for the observable data. According to him, although theories are either true or false, their truth or falsehood is irrelevant for science.

For example, suppose physical theory $T$ for a domain $D$ postulates unobservable entities $E$ that behave in a certain way. Suppose that either such entities do not exist or else that, although they exist, they do not behave as the theory says they do. In both cases the theory would be false but, according to van Fraassen, this is irrelevant to science. The important question is whether a theory correctly describes what is observable in $D$ and it could do so even if it were false. It might correctly predict what will happen in experiments in $D$, correctly describe the empirical laws that operate in $D$, and so on, even if entities $E$ did not exist or did not behave in the way postulated by the theory. Besides empirical adequacy van Fraassen uses pragmatic criteria in judging theories. Among these are mathematical elegance, simplicity, wideness of scope, and explanatory power. However, he stresses that these are not criteria of truth and have no epistemic import. Rather they provide reasons for preferring theories independently of the question of truth. For example, two theories $T_1$ and $T_2$ might both be empirically adequate but $T_1$ might be simpler than $T_2$. For this reason $T_1$ might be preferable -- other things being equal-- to $T_2$. But, says van Fraassen, simplicity is not an epistemological criterion. That $T_1$ is simpler than $T_2$ does not mean that $T_1$ is more likely to be true than $T_2$ or that $T_1$ is closer to the truth than $T_2$.

Contrast With Other Positions
Van Fraassen's view of science should be contrasted with other positions. First, it is different from Scientific Realism, which is the view that science should aim at developing true theories; that is, at theories which correctly describe unobservable entities and their behavior and by so doing explain observable phenomena. For example, realists believe that physics should try to gain knowledge of the unobservable micro-entities, which constitute ordinary physical objects. Given this knowledge a physicist can then predict and explain the behavior of ordinary physical objects. Thus, knowing the unobservable behavior of gas molecules, he or she can predict and explain the observable properties of gas. According to van Fraassen, on the other hand, the only important thing is whether a theory of gas is true of the observable properties of gas; it is irrelevant if unobservable gas molecules behave in the way specified by the theory.

Second, van Fraassen's view differs from Instrumentalism. The latter view holds that scientific theories are neither true nor false but instruments, tools, devices that are useful in predicting and controlling observable phenomena. On one version of Instrumentalism, theories do not take the form of statements but of rules that enable one to make accurate predictions. However, rules are neither true nor false. In contrast, on van Fraassen's view scientific theories are either true or false. The instrumental dimension of theories rest in the fact that pragmatic criteria are relevant to their evaluation.
Third, van Fraassen's view is different from Social Constructivism, which maintains that observable facts are not discovered by empirical investigation about the world but are constructed. According to van Fraassen's view, although one might speak of the unobservable entities of physics as being constructed, this is misleading. For van Fraassen such entities may indeed exist independently of the theories of scientists but whether or not they do is irrelevant to science. One evaluates the postulation of such entities in physical theory by pragmatic criteria, not in terms of whether they are real.

**The Advantages**

Van Fraassen's Constructive Empiricism does not have many of the problems that plague Social Constructivism and Scientific Realism. Social constructivism has been faulted for assuming both a relativistic and a subjective account of truth. Constructive Empiricism does not presuppose either relativism or subjectivism, however, since, according to it, scientific theories are either true or false. Van Fraassen's point is that the only thing that is epistemologically relevant is the empirical adequacy of the theories, that it is whether the theories correctly describe the empirical data.

Social Constructivism has also been criticized for not doing justice to the history of science. It is held, for example, that it can give no account of scientific progress. Constructive Empiricism can, however, give such an account. According to it science is indeed progressing since its theories are now more empirically adequate than they were in the past. At the same time, Constructive Empiricism avoids some of the criticisms made of Scientific Realism. For example, it has been objected that Scientific Realism makes metaphysical assumptions that go beyond all possible empirical evidence. It is said that as a result it generates a deep skepticism since it postulates entities that transcend all possible empirical data. But Constructive Empiricism forsakes metaphysical speculation and is simply concerned with whether scientific theories are empirically adequate. Thus, it argues that whether or not the observable entities of physics are real is beside the scientific point. Another objection to Scientific Realism is that it neglects the nonepistemic factors in scientific theory choice. However, Constructive Empiricism appeals to several pragmatic criteria in the choice between equally empirically adequate theories. Notice however that although pragmatic criteria are allowed, they play a secondary role: it is only after theories are judged empirically adequate that pragmatic criteria enter the picture.

**Implications for Science Education**

Insights from both Social Constructivism and Scientific Realism can be incorporated into science education within a Constructive Empiricist framework even as some of their excesses are avoided. For example, Helge Krågh points out that Social Constructivism's tendency to put N-rays, cold fusion, polywater and other cases of pseudo-science in the same category as successful cases of science would have a disastrous effect on science teaching. He says that from science we know "for sure" that X rays exist and that N-rays do not. Krågh says that "ought to be reason enough to exclude N-rays from the curriculum; or if including the subject, then treat it as a case-study of scientific error." On the other hand, a Social Constructivist might be skeptical of Krågh's
metaphysical claims and argue that both X rays and N rays are in the same metaphysical ballpark: both are fictional constructions of scientists. Van Fraassen's approach avoids the metaphysical controversy altogether by sticking with empirical adequacy. Whatever the reality of N-rays and X-rays, the theories in which they are embedded are different. Theories that postulate X-rays account for the available evidence whereas theories that postulate N-rays do not. Hence, theories that posit N-rays would be excluded from a science curriculum or else would be treated as case studies of error. Social Constructivist in science education has stressed a number of related ideas in regard to science education. For example, they have argued that students learn best by constructing a representation of the world from within rather than from being fed facts from the outside. However, supposing this idea to be correct, it can be easily incorporated into a Constructive Empiricist framework. From this latter perspective students would be taught to construct theories that are empirically adequate; that is, that agree with the evidence. Although students would be free to create theories that postulate unobservable entities, they would learn that the reality of these entities is scientifically irrelevant. Students would also be encouraged to use pragmatic criteria to decide between equally empirically adequate theories while learning that such criteria have no epistemological import.

Ernst von Glaserfeld has argued that science educators should not tell students that they have produced a "wrong" solution but instead should put stress on whether the conceptual model developed by the students is "adequate" and "satisfying." When Scientific Realists hear this they throw up their hands and shake their heads in despair, accusing Social Constructivism of irrational subjectivism. However, whatever von Glaserfeld's intention, his words can be given a different interpretation. From the perspective of Constructive Empiricism science educators should not be concerned with whether a student's model is wrong but only with whether it agrees with the empirical evidence; that is, whether it is empirically adequate. Thus, from this perspective it makes no difference if this agreement is satisfying to the student in some subjective sense. What matters is if it is satisfying from an empirical point of view: if the student model is satisfied when if it correctly describes the empirical data. Von Glaserfeld has also said that Social Constructivism is a form of pragmatism. Thus, not surprisingly pragmatic considerations are brought into his views of science education. For example, he says that a student's conceptual scheme is not a representation of the real world but is adaptive or viable to the subject's experience and that science educators should help students to develop such viable schemes. Although I am not entirely sure what von Glaserfeld means here, Constructive Empiricism can give a plausible account of the pragmatic element without falling into the trap of subjectivism. Presumably van Fraassen would say that von Glaserfeld is correct that scientific theories do not represent the real world, in the sense that the reality of their postulated unobservable entities is irrelevant. He would say they should be judged on their viability in that they accurately describe the empirical evidence. Of course, such empirically accurate theories have pragmatic implications that are not developed by van Fraassen; in particular, they help one to cope with and get around in the world. Pragmatic considerations also enter the picture directly in regard to choosing between different equally viable theories. Different theories will be evaluated differently
in terms of criteria such as simplicity, explanatory power, and scope. The theory one ultimately chooses will depend on the relative strength of these criteria in different contexts. Let me give you a concrete example of how Constructive Empiricism might be used in science education. Some science educators have developed "black box" apparatus-- variously called hypothesis machines or theory boxes-- as classroom tools. An apparatus is presented to the class, but its inner mechanism is hidden. Something is put in the apparatus (the input) and something comes out of it (the output). Students are asked to guess the hidden mechanism that produces the output, given the input. For example, in one apparatus there is a series of parallel transparent tubes. However, the middle section of tubes is covered. When marbles are rolled down a tube they disappear behind the covered section; sometimes they appear again in the same tube on the other side of the covered section, sometimes they appear in a different tube, and sometimes they do not appear at all. Students are asked to guess what hidden mechanism in the covered section has caused the observed behavior of the marbles.

The inventors of the apparatus argue that it teaches students "indirect observation."[13] If one pretends that the hidden mechanism of the apparatus is unobservable in principle, it can be argued alternately that this apparatus teaches the basic principles of Constructive Empiricism. On a Constructive Empiricist interpretation of the black box apparatus, the main job of the students would be to achieve empirical adequacy; that is, to describe accurately the input and the output of the machine. For example, they would describe under what conditions a marble does not appear at all or, if it does appear. They would specify if it appears at random times or if there is some discernible pattern. Student hypotheses about the box's hidden mechanism might be useful in discovering this relation. But, under the supposition that the hidden mechanism is unobservable in principle, the truth of such a hypothesis is irrelevant. Rather their hypotheses of unobservable mechanisms would be judged in terms of pragmatic criteria. Thus, the students would not only be learning to achieve empirical adequacy but would also be learning to develop fruitful hypotheses about hidden mechanisms. Naturally the question remains of how much that is learned under a Constructive Empiricist use of the black box apparatus is transferable to actual scientific practice. However, this question pertains to all science education no matter what approach one takes. Whether science educators take a Social Constructivists or Scientific Realist approach, they must be concerned about whether or not their teachings are applied by their students once they leave the classroom and actually start practicing science. This is where research in science education is useful. Education researchers could explore the question of whether students who learn the Constructive Empiricism approach using a hypotheses machine like the one described above tend to use this approach in scientific laboratories and beyond.

**Conclusion**

I have suggested some of the advantages of van Fraassen's Constructive Empiricism over Social Constructivism and Scientific Realism both in regard to the philosophy of science and science education. However, I do not want to be perceived as suggesting that this approach is free from problems or even that I advocate it. In the philosophy of science critics have raised questions about this approach.
Unit 4

PHILOSOPHICAL FOUNDATIONS OF SCIENCE-II

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INTRODUCTION

This unit gives an overview of different philosophies of Science. During the last decade of the 20th century little progress was made in the field of philosophy of Science. This unit starts with the concept of Falsification in which work of Popper is significant. Next is Rationalism which is defined as rationalism is defined as a methodology or a theory "in which the criterion of the truth is not sensory but intellectual and deductive.

OBJECTIVES

After reading this Unit you will be able to:
1. to understand the concepts of Falsification, Rationalism, Relativism, Realism and Instrumentalism.
4.1. Flasification
Falsifiability of a statement, hypothesis, or theory is the inherent possibility that it can be proven false. A statement is called falsifiable if it is possible to conceive of an observation or an argument which negates the statement in question. In this sense, falsify is synonymous with nullify, meaning to invalidate or "show to be false".

For example, by the problem of induction, no number of confirming observations can verify a universal generalization, such as all swans are white, since it is logically possible to falsify it by observing a single black swan. Thus, the term falsifiability is sometimes synonymous to testability. Some statements, such as It will be raining here in one million years, are falsifiable in principle, but not in practice.[1]

The concern with falsifiability gained attention by way of philosopher of science Karl Popper's scientific epistemology "falsificationism". Popper stresses the problem of demarcation—distinguishing the scientific from the unscientific—and makes falsifiability the demarcation criterion, such that what is unfalsifiable is classified as unscientific, and the practice of declaring an unfalsifiable theory to be scientifically true is pseudoscience.

4.2. Rationalism
In epistemology, rationalism is the view that "regards reason as the chief source and test of knowledge"[1] or "any view appealing to reason as a source of knowledge or justification".[2] More formally, rationalism is defined as a methodology or a theory "in which the criterion of the truth is not sensory but intellectual and deductive".[3]

In an old controversy, rationalism was opposed to empiricism, where the rationalists believed that reality has an intrinsically logical structure. Because of this, the rationalists argued that certain truths exist and that the intellect can directly grasp these truths. That is to say, rationalists asserted that certain rational principles exist in logic, mathematics, ethics, and metaphysics that are so fundamentally true that denying them causes one to fall into contradiction. The rationalists had such a high confidence in reason that empirical proof and physical evidence were regarded as unnecessary to ascertain certain truths – in other words, "there are significant ways in which our concepts and knowledge are gained independently of sense experience".[4]

Different degrees of emphasis on this method or theory lead to a range of rationalist standpoints, from the moderate position "that reason has precedence over other ways of acquiring knowledge" to the more extreme position that reason is "the unique path to knowledge".[5] Given a pre-modern understanding of reason, rationalism is identical to philosophy, the Socratic life of inquiry, or the zetetic (skeptical) clear interpretation of authority (open to the underlying or essential cause of things as they appear to our sense of certainty). In recent decades, Leo Strauss sought to revive "Classical Political Rationalism" as a discipline that understands the task of reasoning, not as foundational, but as maieutic.

In politics, Rationalism, since the Enlightenment, historically emphasized a "politics of reason" centered upon rational choice, utilitarianism, secularism, and irreligion[6]—the latter aspect's antitheism later ameliorated by utilitarian adoption of pluralistic rationalist methods practicable regardless of religious or irreligious ideology.[7][8]
In this regard, the philosopher John Cottingham\(^9\) noted how rationalism, a methodology, became socially conflated with atheism, a worldview:

In the past, particularly in the 17th and 18th centuries, the term 'rationalist' was often used to refer to free thinkers of an anti-clerical and anti-religious outlook, and for a time the word acquired a distinctly pejorative force (thus in 1670 Sanderson spoke disparagingly of 'a mere rationalist, that is to say in plain English an atheist of the late edition...'). The use of the label 'rationalist' to characterize a world outlook which has no place for the supernatural is becoming less popular today; terms like 'humanist' or 'materialist' seem largely to have taken its place. But the old usage still survives.

4.3. **Relativism**

Relativism, roughly put, is the view that truth and falsity, right and wrong, standards of reasoning, and procedures of justification are products of differing conventions and frameworks of assessment and that their authority is confined to the context giving rise to them. More precisely, “relativism” covers views which maintain that—at a high level of abstraction—at least some class of things have the properties they have (e.g., beautiful, morally good, epistemically justified) not *simpliciter*, but only relative to a given framework of assessment (e.g., local cultural norms, individual standards), and correspondingly, that the truth of claims attributing these properties holds only once the relevant framework of assessment is specified or supplied. Relativists characteristically insist, furthermore, that if something is only *relatively* so, then there can be no framework-independent vantage point from which the matter of whether the thing in question is so can be established.

Relativism has been, in its various guises, both one of the most popular and most reviled philosophical doctrines of our time. Defenders see it as a harbinger of tolerance and the only ethical and epistemic stance worthy of the open-minded and tolerant. Detractors dismiss it for its alleged incoherence and uncritical intellectual permissiveness. Debates about relativism permeate the whole spectrum of philosophical sub-disciplines. From ethics to epistemology, science to religion, political theory to ontology, theories of meaning and even logic, philosophy has felt the need to respond to this heady and seemingly subversive idea. Discussions of relativism often also invoke considerations relevant to the very nature and methodology of philosophy and to the division between the so-called “analytic and continental” camps in philosophy. And yet, despite a long history of debate going back to Plato and an increasingly large body of writing, it is still difficult to come to an agreed definition of what, at its core, relativism is, and what philosophical import it has. This entry attempts to provide a broad account of the many ways in which “relativism” has been defined, explained, defended and criticized.

4.4. **Realism**

Realism was an artistic movement that began in France in the 1850s, after the 1848 Revolution. Realists rejected Romanticism, which had dominated French literature and art since the late 18th century. Realism revolted against the exotic subject matter and exaggerated emotionalism and drama of the Romantic Movement.

Philosophical realism is the belief that some aspects of reality are ontologically independent of our conceptual schemes, perceptions, linguistic practices, beliefs, etc.
Realism may be spoken of with respect to other minds, the past, the future, universals, mathematical entities (such as natural numbers), moral categories, the material world, and thought. Realism can also be promoted in an unqualified sense, in which case it asserts the mind-independent existence of the world, as opposed to skepticism and solipsism. Philosophers who profess realism often claim that truth consists in a correspondence between cognitive representations and reality.\[^1\]

Realists tend to believe that whatever we believe now is only an approximation of reality but that the accuracy and fullness of understanding can be improved.\[^2\] In some contexts, realism is contrasted with idealism. Today it is more usually contrasted with anti-realism, for example in the philosophy of science.

Realism was an artistic movement that began in France in the 1850s, after the 1848 Revolution.\[^1\] Realists rejected Romanticism, which had dominated French literature and art since the late 18th century. Realism revolted against the exotic subject matter and exaggerated emotionalism and drama of the Romantic movement. Instead it sought to portray real and typical contemporary people and situations with truth and accuracy, and not avoiding unpleasant or sordid aspects of life. Realist works depicted people of all classes in situations that arise in ordinary life, and often reflected the changes brought by the Industrial and Commercial Revolutions. The popularity of such "realistic" works grew with the introduction of photography—a new visual source that created a desire for people to produce representations which look objectively real.

The Realists depicted everyday subjects and situations in contemporary settings, and attempted to depict individuals of all social classes in a similar manner. Classical idealism and Romantic emotionalism and drama were avoided equally, and often sordid or untidy elements of subjects were not smoothed over or omitted. Social realism emphasizes the depiction of the working class, and treating them with the same seriousness as other classes in art, but realism, as the avoidance of artificiality, in the treatment of human relations and emotions was also an aim of Realism. Treatments of subjects in a heroic or sentimental manner were equally rejected.\[^2\]

Realism as an art movement was led by Gustave Courbet in France. It spread across Europe and was influential for the rest of the century and beyond, but as it became adopted into the mainstream of painting it becomes less common and useful as a term to define artistic style. After the arrival of Impressionism and later movements which downgraded the importance of precise illusionistic brushwork, it often came to refer simply to the use of a more traditional and tighter painting style. It has been used for a number of later movements and trends in art, some involving careful illusionistic representation, such as Photorealism, and others the depiction of "realist" subject matter in a social sense, or attempts at both.

### 4.5. Instrumentalism

Instrumentalism is one of a multitude of modern schools of thought created by scientists and philosophers throughout the 20th century. It is named for its premise that theories are tools or instruments identifying reliable means-end relations found in experience, but not claiming to reveal realities beyond experience.\[^1\] Its premises and practices were most
clearly and persuasively stated by two philosophers, John Dewey (1859-1952) and Karl Popper (1902-1994). Independently, they defined the school quite similarly, but their judgments of its premises were irreconcilable.

Dewey was a practitioner of instrumentalism, accepting means-end relations as discoverable by joining inductive and deductive reasoning about experience. Popper was a critic of the school. He insisted that induction is not scientifically valid, and that realities can be known without experience. These contrary judgments endowed the school with the legacy of confusion and ambiguity described below.

This article gives the definition of instrumentalism accepted by these two philosophers. It explains the grounds of their irreconcilable judgments, which are still embedded in popular understanding of the school, and describes the practice of followers of each philosopher, demonstrating that neither philosopher's judgments have achieved universal assent, leaving the school's meaning and legitimacy in modern scientific inquiry indeterminate.

In 1925, John Dewey published an article entitled "The Development of American Pragmatism," in which he defined instrumentalism to distinguish it from schools known as "pragmatism" and "experimentalism." In 1956, Karl Popper published an article entitled "Three Views Concerning Human Knowledge," in which he defined instrumentalism to distinguish it from "essentialism" and a "third view"—his own—which he came to call "critical rationalism."

Dewey's article was republished in 1984 in John Dewey: The Later Works. Popper's article was republished in 1962 in Conjectures and Refutations. The following four premises defining instrumentalism are taken from these sources. Premises 1 and 2 were accepted by both philosophers and the general public. Premises 3 and 4 were and remain controversial.

1) **Theories are tools-of-the-trade of thinking, seeking to map means-ends relationships found in experience.**
   
   **Dewey:**
   "Instrumentalism is an attempt to establish a precise logical theory of concepts, of judgments and inferences in their various forms, by considering primarily how thought functions in the experimental determinations of future consequences."[2]:14

   **Popper:**
   Instrumentalism endorses "the interpretation of scientific theories as practical instruments or tools for such purposes as the prediction of impending events."[3]:62-3

2) **Theories predict consequences of using means to achieve ends.**
   
   **Dewey:**
   "The verification of a theory … is carried on by the observation of particular facts."[2]:11

   **Popper:**
   "… we submit [theories] to severe tests by trying to deduce from them some of the regularities of the known world of common experience."[3]:102
3) Theory-development requires inductive reasoning, basing general statements on limited observations of facts-of-the-case.

Dewey:
An empirical philosopher must "... first find particular cases from which he then generalizes. I am "... an opponent of the widely accepted dogma of inductivism—of the view that science starts from observation and proceeds, by induction, to generalizations, and ultimately to theories."

4) There are no realities behind or beyond what can be known by applying instrumental theories.

Dewey:
"It is therefore in submitting conceptions to the control of experience... that one finds examples of what is called truth

4.6. Logical Positivism

Also known as logical empiricism and neo-positivism, this philosophical school was born in Austria and Germany during the 1920s, and was primarily concerned with the logical analysis of scientific knowledge. Among its members were Moritz Schlick, the founder of the Vienna Circle, Rudolf Carnap, the leading exponent of logical positivism, Hans Reichenbach, the founder of the Berlin Circle, Alfred Jules Ayer, Herbert Feigl, Philipp Frank, Kurt Grelling, Hans Hahn, Carl Gustav Hempel, Victor Kraft, Otto Neurath, and Friedrich Waismann. Logical positivists denied the soundness of metaphysics and traditional philosophy; they asserted that many philosophical problems are indeed meaningless. During the 1930s, when Nazism gained power in Germany, the most prominent proponents of logical positivism immigrated to the United States, where they considerably influenced American philosophy. Until the 1950s, logical positivism was the leading school in the philosophy of science. Nowadays, the influence of logical positivism persists especially in the way philosophy is practiced. This influence is particularly noticeable in the attention philosophers give to the analysis of scientific thought and to the integration of results from technical research on formal logic and the theory of probability.

The Main Philosophical Tenets of Logical Positivism. a). Verifiability Principle. According to logical positivism, there are only two sources of knowledge: logical reasoning and empirical experience. The former is analytic a priori, while the latter is synthetic a posteriori; hence synthetic a priori knowledge does not exist. It is precisely in the rejection of the possibility of synthetic knowledge a priori that the basic thesis of modern empiricism lies. (Wissenschaftliche Weltanschauung. Der Wiener Kreis, 1929; English translation The Scientific Conception of the World. The Vienna Circle, in Sarkar, Sahotra (ed.), The Emergence of Logical Empiricism: from 1900 to the Vienna Circle, New York: Garland Publishing, 1996, p. 330). Logical knowledge includes mathematics, which is claimed to be reducible to formal logic. Empirical knowledge includes physics, biology, psychology, etc. Experience is the only judge of scientific theories; however, logical positivists were aware that scientific knowledge does not exclusively rise from the experience: scientific theories are genuine hypotheses that go beyond the experience. It is not possible to establish a logically durable building on verifications [verification is an observational statement about immediate perception], for they are already vanished when the building begins. If they were, with respect to time, at the beginning of the knowledge, then they would be logically useless. On the contrary, there is a great difference when
...From a logical point of view, nothing depends on them: they are not premises but a firm end point. (M. Schlick, "Über das Fundament der Erkenntnis", in Erkenntnis, 4, 1934).b. Elimination of Metaphysics. The attitude of logical positivism towards metaphysics is well expressed by Carnap in the article Überwindung der Metaphysik durch Logische Analyse der Sprache in Erkenntnis, vol. 2, 1932 (English translation The Elimination of Metaphysics Through Logical Analysis of Language.) Alanguage — says Carnap — consists of a vocabulary, i.e. a set of meaningful words, and a syntax, i.e. a set of rules governing the formation of sentences from the words of the vocabulary. Pseudo-statements, i.e. sequences of words that at first sight resemble statements but in reality have no meaning, are formed in two ways: either meaningless words occur in them, or they are formed in an invalid syntactical way. According to Carnap, pseudo-statements of both kinds occur in metaphysics. A word W has a meaning if two conditions are satisfied. First, the mode of the occurrence of W initiates elementary sentence form (i.e. the simplest sentence form in which W is capable of occurring) must be fixed. Second, if W occurs is an elementary sentence S, it is necessary to give an answer to the following questions (that are — according to Carnap — equivalent formulation of the same question): (1) what sentences is S deducible from, and what sentences are deducible from S? (2) Under what conditions are S supposed to be true, and under what conditions false? (3) How S is to verified? (4) What is the meaning of S? (R. Carnap, The Elimination of Metaphysics Through Logical Analysis of Language in Sarkar, Sahotra (ed.), Logical Empiricism at its Peak: Schlick, Carnap, and Neurath, New York: Garland Pub., 1996, p. 63)

An example offered by Carnap concerns the word "arthropode". The sentence form "the thing x is an arthropod" is an elementary sentence form that is derivable from "x is an animal", "x has a segmented body" and "x has jointed legs". Conversely, these sentences are derivable from "the thing is an arthropode". Thus the meaning of the words "arthropode" is determined. According to Carnap, many words of metaphysics do not fulfill these requirements and thus they are meaningless. As an example, Carnap considers the word "principle". This word has a definite meaning, if the sentence "x is the principle of y" is supposed to be equivalent to the sentences "exists by virtue of x" or "y arises out of x". The latter sentence is perfectly clear: y arises out of when x is invariably followed by y, and the invariable association between x and y is empirically verifiable. But — says Carnap — metaphysicians are not satisfied with this interpretation of the meaning of "principle". They assert that no empirical relations between x and y can completely explain the meaning of "x is the principle of y", because there is something that cannot be grasped by means of the experience, something for which no empirical criterion can be specified. It is shellacking of any empirical criterion — says Carnap — that deprives of meaning the word "principle" when it occurs in metaphysics. Metaphysical pseudo-statements such as "water is the principle of the world" or "the spirit is the principle of the world" are void of meaning because a meaningless word occurs in them. There are also pseudo-statements that consist of meaningful words. An example is the word sequence "Caesar is a prime number" that has the same form of "Caesar is a general". These two sentences are well formed in English, because there is not a grammatical distinction between predicates which can be affirmed of human beings (such as "general") and predicates which can be affirmed of numbers (such as "prime number"). Although every word occurring in "Caesar is prime number" has a definite meaning, the sequence evidently has no meaning. In a logically constructed language - says Carnap - a distinction between the different kinds of predicates is specified, and pseudo-statements as "Caesar is a prime number" could not arise. Metaphysical statements which do not contain meaningless words are indeed meaningless because they are formed in a
way which is admissible in natural languages but not admissible in logically constructed languages. What are the most frequent sources of errors from which metaphysical pseudo-statements arise? A source of mistakes is the ambiguity of the verb "to be", which is sometimes used as a copula ("I am hungry") and sometimes to designate existence ("I am"). The latter statement incorrectly suggests predicative form, and thus it suggests that existence is a predicate. Modern logic has introduced an explicit sign to designate existence (the sign ), which occurs only in statements such as xP(x). Therefore modern logic has clarified that existence is not a predicate, and has revealed the logical error from which pseudo-statements such as "cogito, ergo sum" arose. Another source of mistakes is type confusion, in which a predicate is used as predicate of a different type (see the example "Caesar is a prime number"). What is the role of metaphysics? According to Carnap, although metaphysics has not theoretical content, it has a content indeed: metaphysical pseudo-statements express the attitude of a person towards life. The metaphysician, instead of using the medium of art, works with the medium of the theoretical; he confuses art with science, attitude towards life with knowledge, and thus produces an unsatisfactory and inadequate work. "Metaphysicians are musicians without musical ability" (Carnap, The Elimination of Metaphysics, in Sarkar, Sahota (ed.), Logical Empiricism at its Peak, p. 30).

The Language of Science. According to logical positivism, a scientific theory is an axiomatic system that acquires an empirical interpretation only by means of appropriate statements called rules of correspondence, which establish a correlation between real objects (or real processes) and the abstract concepts of the theory? Without such type of statements a theory lacks of a physical interpretation and it is not verifiable, but it is an abstract formal system, whose only requirement is axioms consistency. The language of a theory includes three kinds of terms: 1. Logical terms, which include all mathematical terms. 2. Observational terms, which denote objects or properties that can be directly observed or measured. 3. Theoretical terms, which denote objects or properties we cannot observe or measure but we can only infer from direct observations. According to this distinction, the statements of a theory are divided in three sets: 1. Logical statements, which include only logical terms. 2. Observational statements, which include observational and logical terms. 3. Theoretical statements, which include theoretical, observational and logical terms. Theoretical statements are divided in: • Pure theoretical statements, which do not include observational terms. • Mixed theoretical statements, which include observational terms. Rules of correspondence belong to this set of statements. The following table represents the diverse kinds of statements. Statements-statements O-statements T-statements L-terms L-terms O-terms Pure T-statements Mixed T-statements L-terms T-terms O-terms T-terms L-terms With respect to the method of ascertaining their truth or falsity, the statements of a scientific theory are divided in two sets: 1. Analytic a priori statements, whose truth is based on the meaning of the terms of the language. They include logical statements, whose truth is based only on the rules of logic and mathematics. 2. Synthetic a posteriori statements, which are the not-analytic statements. Another distinction is between: 1. Ax-true or Ax-false statements, which are either a logical consequence of the axioms of the theory or incompatible with the axioms. 2. Contingent statements, which are independent from the axioms of the theory. The following table represents the diverse kinds of statements. True Contingent False Ax-true Synthetic a posteriori Ax-false Analytic a priori true Logical true Possible Analytic a priori false Logical false The main points of this thesis about the structure of scientific theories are: • The distinction between observational and theoretical term.
PSYCHOLOGICAL FOUNDATIONS OF SCIENCE EDUCATION-I

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INTRODUCTION

A theoretical framework based on cognitive/developmental research is described. It is argued that science learning is a gradual process during which initial conceptual structures based on children's interpretations of everyday experience are continuously enriched and restructured. Conceptual change also involves increased metaconceptual awareness, cognitive flexibility, and theoretical coherence. Some of the implications of this research for the development of science curricula and for instruction are discussed. It is also argued that while cognitive/developmental research can provide us with important information about the process of learning science, it does not provide much information about the external, environmental variables that can facilitate cognitive performance and conceptual change. What is needed in the future is the development of a theory of learning that bridges science education and cognitive/developmental research. Such a theory should specify the mechanisms that can take an individual from one level of cognitive performance to the next and relate them to situational and cultural factors.

OBJECTIVES

After reading this unit you will be able to:
1. understand the concepts of science and teaching.
2. know about learning theories of psychology in scientific perspective.
3. know the concepts of solo and B.Bloom taxonomy.
4. S&R Theories and science teaching.
5.1 IVAN PETROVICH PAVLOV

(Russian: Ива́н Петро́вич Па́влов; IPA: [ɪˈvan pʲɪˈtrovʲɪtɕ pəˈvlʲof] (listen); 26 September [O.S. 14 September] 1849 – 27 February 1936) was a Russian physiologist known primarily for his work in classical conditioning. From his childhood days Pavlov demonstrated intellectual curiosity along with an unusual energy which he referred to as "the instinct for research".[3] Inspired by the progressive ideas which D. I. Pisarev, the most eminent of the Russian literary critics of the 1860s, and I. M. Sechenov, the father of Russian physiology, were spreading, Pavlov abandoned his religious career and devoted his life to science. In 1870 he enrolled in the physics and mathematics department at the University of Saint Petersburg in order to study natural science.[2] Pavlov won the Nobel Prize for Physiology or Medicine in 1904,[3][4] becoming the first Russian Nobel laureate. A Review of General Psychology survey, published in 2002, ranked Pavlov as the 24th most cited psychologist of the 20th century.[5] Pavlov's principles of classical conditioning have been found to operate across a variety of experimental and clinical settings, including educational classrooms.

Education and Early Life

The Pavlov Memorial Museum, Ryazan: Pavlov's former home, built in the early 19th century[7]

Ivan Pavlov, the eldest of eleven children,[8] was born in Ryazan, Russian Empire. His father, Peter Dmitrievich Pavlov (1823–1899), was a village Russian orthodox priest.[9] His mother, Varvara Ivanovna Uspenskaya (1826–1890), was a devoted homemaker. As a child, Pavlov willingly participated in house duties such as doing the dishes and taking care of his siblings. He loved to garden, ride his bicycle, row, swim, and play gorodki; he devoted his summer vacations to these activities.[10] Although able to read by the age of 7, Pavlov was seriously injured when he fell from a high wall onto stone pavement,[11] he did not undergo formal schooling until he was 11 years old as a result of his injuries.[8]

Pavlov attended and graduated from the Ryazan church school before entering the local theological seminary. However, in 1870, Pavlov left the seminary without graduating to attend the university at St. Petersburg where he enrolled in the physics and math department and took natural science courses. In his fourth year, his first research project
on the physiology of the nerves of the pancreas[12] won him a prestigious university award. In 1875, Pavlov completed his course with an outstanding record and received the degree of Candidate of Natural Sciences. However, impelled by his overwhelming interest in physiology, he decided to continue his studies and proceeded to the Imperial Academy of Medical Surgery. While at the Academy of Medical Surgery, Pavlov became an assistant to his former teacher, Tyson, but left the department when Tyson was replaced by another instructor.

After some time, Pavlov obtained a position as a laboratory assistant to Professor Ustimovich at the physiological department of the Veterinary Institute.[13] For two years, Pavlov investigated the circulatory system for his medical dissertation.[8] In 1878, Professor S.P. Botkin, a famous Russian clinician, invited the gifted young physiologist to work in the physiological laboratory as the clinic's chief. In 1879, Pavlov graduated from the Medical Military Academy with a gold medal award for his research work. After a competitive examination, Pavlov won a fellowship at the Academy for postgraduate work.[14] The fellowship and his position as Director of the Physiological Laboratory at the clinic of the famous Russian clinician, S. P. Botkin enabled Pavlov to continue his research work. In 1883, he presented his doctor's thesis on the subject of The centrifugal nerves of the heart and posited the idea of nervism and the basic principles on the trophic function of the nervous system. Additionally, his collaboration with the Botkin clinic produced evidence of a basic pattern in the regulation of reflexes in the activity of circulatory organs.

Ivan Pavlov

Influences
He was inspired to forsake his Orthodox Christian background and pursue a scientific career by D. I. Pisarev, a literary critique and natural science advocate of the time and I. M. Sechenov, a Russian physiologist, whom Pavlov described as 'The father of physiology'.[9]
After completing his doctorate, Pavlov went to Germany where he studied in Leipzig with Carl Ludwig and Eimear Kelly in the Heidenhain laboratories in Breslau. He remained there from 1884 to 1886. Heidenhain was studying digestion in dogs, using an exteriorized section of the stomach. However, Pavlov perfected the technique by overcoming the problem of maintaining the external nerve supply. The exteriorized section became known as the Heidenhain or Pavlov pouch. After two years (1884–1886), Pavlov returned from Germany to look for a new position. His application for the chair of physiology at the University of Saint Petersburg was rejected. Eventually, Pavlov was given the chair of pharmacology at Tomsk University and then at the University of Warsaw. However, he went to neither place. In 1890, he was appointed the role of professor of Pharmacology at the Military Medical Academy and occupied the position for 5 years. In 1891, Pavlov was invited to the Imperial Institute of Experimental Medicine in St. Petersburg to organize and direct the Department of Physiology. Over a 45-year period, under his direction it became one of the most important centers of physiological research. While Pavlov directed the Department of Physiology at the Institute, he also transferred to the chair of physiology at the Medical Military Academy. This change in positions at the Academy occurred in 1895. He headed the physiology department at the Academy continuously for three decades. Also, starting in 1901, Pavlov was nominated for the Nobel Prize in Physiology or Medicine for four successive years. However, he did not win because his nominations were not specific to any discovery and were based on a variety of laboratory findings. In 1904, Pavlov was awarded the Nobel Prize "in recognition of his work on the physiology of digestion, through which knowledge on vital aspects of the subject has been transformed and enlarged".

While at the Institute of Experimental Medicine he carried out his classical experiments on the digestive glands which is how he eventually won the Nobel prize mentioned above. Pavlov investigated the gastric function of dogs, and later, children by externalizing a salivary gland so he could collect, measure, and analyze the saliva and what response it had to food under different conditions. He noticed that the dogs tended to salivate before food was actually delivered to their mouths, and set out to investigate this "psychic secretion", as he called it. Pavlov’s laboratory housed a full-scale kennel for the experimental animals. Pavlov was interested in observing their long-term physiological processes. This required keeping them alive and healthy in order to conduct chronic experiments, as he called them. These were experiments over time, designed to understand the normal functions of animals. This was a new kind of study, because previously experiments had been “acute,” meaning that the dog went through vivisection and was ultimately killed in the process.

A 1921 article by S. Morgulis in the journal Science, came as a critique of Pavlov's work in that it addressed concerns about the environment in which these experiments had been performed. Based on a report from H. G. Wells, claiming that Pavlov grew potatoes and carrots in his lab, the article stated, "It is gratifying to be assured that Professor Pavlov is raising potatoes only as a pastime and still gives the best of his genius to scientific investigation". Also in 1921, Pavlov began holding laboratory meetings known as the
'Wednesday meetings' where he spoke bluntly on many topics, including his views on psychology. These meetings lasted until he died in 1936.[17]

Pavlov in 1935, by Mikhail Nesterov

Pavlov was highly regarded by the Soviet government, and he was able to continue his research until he reached a considerable age. He was praised by Lenin.[21] However, despite the praise from the Soviet Union government, the money that poured out to support his laboratory, and the honours he was given, Pavlov made no attempts to conceal the disapproval and contempt in which he held Soviet Communism.[22] For example, in 1923 he claimed that he would not sacrifice even the hind leg of a frog to the type of social experiment that the regime was conducting in Russia. Also, in 1927, he wrote to Stalin protesting at what was being done to Russian intellectuals and saying he was ashamed to be a Russian.[3] After the murder of Sergei Kirov in 1934, Pavlov wrote several letters to Molotov criticizing the mass persecutions which followed and asking for the reconsideration of cases pertaining to several people he knew personally.[3]

Conscious until his very last moment, Pavlov asked one of his students to sit beside his bed and to record the circumstances of his dying. He wanted to create unique evidence of subjective experiences of this terminal phase of life.[23] Pavlov died of double pneumonia at the age of 86. He was given a grandiose funeral, and his study and laboratory were preserved as a museum in his honour.[3]

Pavlov contributed to many areas of physiology and neurological sciences. Most of his work involved research in temperament,[citation needed] conditioning and involuntary reflex actions. Pavlov performed and directed experiments on digestion, eventually publishing *The Work of the Digestive Glands* in 1897, after 12 years of research. His experiments earned him the 1904 Nobel Prize in Physiology and Medicine.[24] These experiments included surgically extracting portions of the digestive system from animals, severing nerve bundles to determine the effects, and implanting fistulas between digestive organs and an external pouch to examine the organ's contents. This research served as a base for broad research on the digestive system.
Further work on reflex actions involved involuntary reactions to stress and pain. Pavlov extended the definitions of the four temperament types under study at the time: phlegmatic, choleric, sanguine, and melancholic, updating the names to "the strong and impetuous type, the strong equilibrated and quiet type, the strong equilibrated and lively type, and the weak type." Pavlov and his researchers observed and began the study of transmarginal inhibition (TMI), the body's natural response of shutting down when exposed to overwhelming stress or pain by electric shock. This research showed how all temperament types responded to the stimuli the same way, but different temperaments move through the responses at different times. He commented "that the most basic inherited difference. .. was how soon they reached this shutdown point and that the quick-to-shut-down have a fundamentally different type of nervous system."[26]

**Pavlov on Education**

The basics of Pavlov's classical conditioning serve as a historical backdrop for current learning theories.[27] However, the Russian physiologist's initial interest in classical conditioning occurred almost by accident during one of his experiments on digestion in dogs.[28] Considering that Pavlov worked closely with animals throughout many of his experiments, his early contributions were primarily about animal learning. However, the fundamentals of classical conditioning have been examined across many different organisms, including humans.[28] The basic underlying principles of Pavlov's classical conditioning have extended to a variety of settings, such as classrooms and learning environments.

Classical conditioning focuses on using preceding conditions to alter behavioral reactions. The principles underlying classical conditioning have influenced preventative antecedent control strategies used in the classroom.[29] Classical conditioning set the groundwork for the present day behavior modification practices, such as antecedent control. Antecedent events and conditions are defined as those conditions occurring before the behavior.[30] Pavlov's early experiments used manipulation of events or stimuli preceding behavior (i.e., a tone) to produce salivation in dogs much like teachers manipulate instruction and learning environments to produce positive behaviors or decrease maladaptive behaviors. Although he did not refer to the tone as an antecedent, Pavlov was one of the first scientists to demonstrate the relationship between environmental stimuli and behavioral responses. Pavlov systematically presented and withdrew stimuli to determine the antecedents that were eliciting responses, which is similar to the ways in which educational professionals conduct functional behavior assessments.[31] Antecedent strategies are supported by empirical evidence to operate implicitly within classroom environments. Antecedent-based interventions are supported by research to be preventative, and to produce immediate reductions in problem behaviors.

**5.2. Skinner’s Theory and Science Teaching**

**Burrhus Frederic Skinner** (March 20, 1904 – August 18, 1990), commonly known as **B. F. Skinner**, was an American psychologist, behaviorist, author, inventor, and social
philosopher. He was the Edgar Pierce Professor of Psychology at Harvard University from 1958 until his retirement in 1974.

Skinner considered free will an illusion and human action dependent on consequences of previous actions. If the consequences are bad, there is a high chance the action will not be repeated; if the consequences are good, the actions that led to it being repeated become more probable. Skinner called this the principle of reinforcement.

To strengthen behavior, Skinner used operant conditioning, and he considered the rate of response to be the most effective measure of response strength. To study operant conditioning he invented the operant conditioning chamber, also known as the Skinner Box, and to measure rate he invented the cumulative recorder. Using these tools, he and C. B. Ferster produced his most influential experimental work, which appeared in the book Schedules of Reinforcement.

Skinner developed a philosophy of science that he called radical behaviorism and founded a school of experimental research psychology—the experimental analysis of behavior. He imagined the application of his ideas to the design of a human community in his utopian novel, Walden Two, and his analysis of human behavior culminated in his work, Verbal Behavior. Skinner was a prolific author who published 21 books and 180 articles. Contemporary academia considers Skinner a pioneer of modern behaviorism, along with John B. Watson and Ivan Pavlov. A June 2002 survey listed Skinner as the most influential psychologist of the 20th century.

**Biography**

The gravestone of B.F. Skinner and his wife Eve at Mount Auburn Cemetery. Skinner was born in Susquehanna, Pennsylvania, to Grace and William Skinner. His father was a lawyer. He became an atheist after a Christian teacher tried to assuage his fear of the hell that his grandmother described. His brother Edward, two and a half years younger, died at age sixteen of a cerebral hemorrhage. He attended Hamilton College in New York with the intention of becoming a writer. He found himself at a social disadvantage at Hamilton College because of his intellectual attitude. While attending, he joined Lambda Chi Alpha fraternity. He wrote for the school paper, but, as an atheist, he was critical of the religious school he attended. After receiving his Bachelor of Arts in English literature in 1926, he attended Harvard University, where he would later research, teach, and eventually become a prestigious board member. While he was at Harvard, a fellow student, Fred Keller, convinced Skinner that he could make an experimental science from the study of behavior. This led Skinner to invent his prototype for the Skinner Box and to join Keller in the creation of other tools for small experiments. After graduation, he unsuccessfully tried to write a great novel while he lived with his parents, a period that he later called the Dark Years. He became disillusioned with his literary skills despite encouragement from the renowned poet Robert Frost, concluding that he had little world experience and no strong personal perspective from which to write. His encounter with John B. Watson's *Behaviorism* led...
him into graduate study in psychology and to the development of his own version of behaviorism.[20]

Skinner received a Ph.D. from Harvard in 1931, and remained there as a researcher until 1936. He then taught at the University of Minnesota at Minneapolis and later at Indiana University, where he was chair of the psychology department from 1946–1947, before returning to Harvard as a tenured professor in 1948. He remained at Harvard for the rest of his life. In 1973, Skinner was one of the signers of the Humanist Manifesto II.[21]

In 1936, Skinner married Yvonne (Eve) Blue. The couple had two daughters, Julie (m. Vargas) and Deborah (m. Buzan).[22][23] Yvonne Skinner died in 1997,[24] and is buried in Mount Auburn Cemetery, Cambridge, Massachusetts.[25]

Skinner continued to write and work until just before his death. Just a few days before his death, he was given a lifetime achievement award by the American Psychological Association, and delivered a 15-minute address concerning his work.[26]

A controversial figure, Skinner has been depicted in many different ways. He has been widely revered for bringing a much-needed scientific approach to the study of human behavior; he has also been vilified for attempting to apply findings based largely on animal experiments to human behavior in real-life settings.

5.3. Contributions to Psychological Theory (Behaviorism and Radical Behaviorism)

Skinner called his approach to the study of behavior radical behaviorism.[27] This philosophy of behavioral science assumes that behavior is a consequence of environmental histories of reinforcement, (see Applied behavior analysis). In contrast to the approach of cognitive science, behaviorism does not accept private events such as thinking, perceptions, and unobservable emotions as causes of an organism's behavior. However, in contrast to methodological behaviorism, Skinner's radical behaviorism did accept thoughts, emotions, and other "private events" as responses subject to the same rules as overt behavior. In his words:

The position can be stated as follows: what is felt or introspectively observed is not some nonphysical world of consciousness, mind, or mental life but the observer's own body. This does not mean, as I shall show later, that introspection is a kind of psychological research, nor does it mean (and this is the heart of the argument) that what are felt or introspectively observed are the causes of the behavior. An organism behaves as it does because of its current structure, but most of this is out of reach of introspection. At the moment we must content ourselves, as the methodological behaviorist insists, with a person's genetic and environment histories. What are introspectively observed are certain collateral products of those histories...

In this way we repair the major damage wrought by mentalism. When what a person does [is] attributed to what is going on inside him, investigation is brought to an end. Why explain the explanation? For twenty five hundred years people have been preoccupied
with feelings and mental life, but only recently has any interest been shown in a more precise analysis of the role of the environment. Ignorance of that role led in the first place to mental fictions, and it has been perpetuated by the explanatory practices to which they gave rise.[28]

Theoretical Structure
Skinner's behavioral theory was largely set forth in his first book, *Behavior of Organisms.*[29] Here he gave a systematic description of the manner in which environmental variables control behavior. He distinguished two sorts of behavior—respondent and operant—which are controlled in different ways. Respondent behaviors are elicited by stimuli, and may be modified through respondent conditioning, which is often called "Pavlovian conditioning" or "classical conditioning", in which a neutral stimulus is paired with an eliciting stimulus. Operant behaviors, in contrast, are "emitted", meaning that initially they are not induced by any particular stimulus. They are strengthened through operant conditioning, sometimes called "instrumental conditioning", in which the occurrence of a response yields a reinforcer. Respondent behaviors might be measured by their latency or strength, operant behaviors by their rate. Both of these sorts of behavior had already been studied experimentally, for example, respondents by Pavlov,[30] and operants by Thorndike.[31] Skinner's account differed in some ways from earlier ones,[32] and was one of the first accounts to bring them under one roof.

The idea that behavior is strengthened or weakened by its consequences raises several questions. Among the most important are these: (1) Operant responses are strengthened by reinforcement, but where do they come from in the first place? (2) Once it is in the organism's repertoire, how is a response directed or controlled? (3) How can very complex and seemingly novel behaviors be explained?[clarification needed]

Origin of Operant Behavior
Skinner's answer to the first question was very much like Darwin's answer to the question of the origin of a "new" bodily structure, namely, variation and selection. Similarly, the behavior of an individual varies from moment to moment; a variation that is followed by reinforcement is strengthened and becomes prominent in that individual's behavioral repertoire. "Shaping" was Skinner's term for the gradual modification of behavior by the reinforcement of desired variations. As discussed later in this article, Skinner believed that "superstitious" behavior can arise when a response happens to be followed by reinforcement to which it is actually unrelated.

Control of Operant Behavior
The second question, "how is operant behavior controlled?" arises because, to begin with, the behavior is "emitted" without reference to any particular stimulus. Skinner answered this question by saying that a stimulus comes to control an operant if it is present when the response is reinforced and absent when it is not. For example, if lever-pressing only brings food when a light is on, a rat, or a child, will learn to press the lever only when the light is on. Skinner summarized this relationship by saying that a discriminative stimulus (e.g. light) sets the occasion for the reinforcement (food) of the operant (lever-press).
This "three-term contingency" (stimulus-response-reinforcer) is one of Skinner's most important concepts, and sets his theory apart from theories that use only pair-wise associations.[32]

**Explaining Complex Behavior**

Most behavior of humans cannot easily be described in terms of individual responses reinforced one by one, and Skinner devoted a great deal of effort to the problem of behavioral complexity. Some complex behavior can be seen as a sequence of relatively simple responses, and here Skinner invoked the idea of "chaining." Chaining is based on the fact, experimentally demonstrated, that a discriminative stimulus not only sets the occasion for subsequent behavior, but it can also reinforce a behavior that precedes it. That is, a discriminative stimulus is also a "conditioned reinforcer." For example, the light that sets the occasion for lever pressing may also be used to reinforce "turning around" in the presence of a noise. This results in the sequence "noise - turn-around - light - press lever - food." Much longer chains can be built by adding more stimuli and responses.

However, Skinner recognized that a great deal of behavior, especially human behavior, cannot be accounted for by gradual shaping or the construction of response sequences.[33] Complex behavior often appears suddenly in its final form, as when a person first finds his way to the elevator by following instructions given at the front desk. To account for such behavior, Skinner introduced the concept of rule-governed behavior. First, relatively simple behaviors come under the control of verbal stimuli: the child learns to "jump", "open the book", and so on. After a large number of responses come under such verbal control, a sequence of verbal stimuli can evoke an almost unlimited variety of complex responses.[33]

**Reinforcement**

Reinforcement, a key concept of behaviorism, is the primary process that shapes and controls behavior, and occurs in two ways, "positive" and "negative." In *The Behavior of Organisms* (1938), Skinner defined "negative reinforcement" to be synonymous with punishment, that is, the presentation of an aversive stimulus. Subsequently, in *Science and Human Behavior* (1953), Skinner redefined negative reinforcement. In what has now become the standard set of definitions, positive reinforcement is the strengthening of behavior by the occurrence of some event (e.g., praise after some behavior is performed), whereas negative reinforcement is the strengthening of behavior by the removal or avoidance of some aversive event (e.g., opening and raising an umbrella over your head on a rainy day is reinforced by the cessation of rain falling on you).

Both types of reinforcement strengthen behavior, or increase the probability of a behavior reoccurring; the difference is in whether the reinforcing event is something applied (positive reinforcement) or something removed or avoided (negative reinforcement). Punishment is the application of an aversive stimulus/event (positive punishment or punishment by contingent stimulation) or the removal of a desirable stimulus (negative punishment or punishment by contingent withdrawal). Though punishment is often used to suppress behavior, Skinner argued that this suppression is temporary and has a number
of other, often unwanted, consequences. Extinction is the absence of a rewarding stimulus, which weakens behavior.

Writing in 1981, Skinner pointed out that Darwinian natural selection is, like reinforced behavior, "selection by consequences." Though, as he said, natural selection has now "made its case", he regretted that essentially the same process, "reinforcement", was less widely accepted as underlying human behavior.

**Schedules of Reinforcement**

Skinner recognized that behavior is typically reinforced more than once, and, together with C. B. Ferster, he did an extensive analysis of the various ways in which reinforcements could be arranged over time, which he called "schedules of reinforcement."

The most notable schedules of reinforcement studied by Skinner were continuous, interval (fixed or variable), and ratio (fixed or variable). All are methods used in operant conditioning.

- **Continuous reinforcement (CRF)** — each time a specific action is performed the subject receives a reinforcement. This method is effective when teaching a new behavior because it quickly establishes an association between the target behavior and the reinforcer.

- **Interval Schedules** — based on the time intervals between reinforcements

  - **Fixed Interval Schedule (FI)**: A procedure in which reinforcements are presented at fixed time periods, provided that the appropriate response is made. This schedule yields a response rate that is low just after reinforcement and becomes rapid just before the next reinforcement is scheduled.

  - **Variable Interval Schedule (VI)**: A procedure in which behavior is reinforced after random time durations following the last reinforcement. This schedule yields steady responding at a rate that varies with the average frequency of reinforcement.

- **Ratio Schedules** — based on the ratio of responses to reinforcements

  - **Fixed Ratio Schedule (FR)**: A procedure in which reinforcement is delivered after a specific number of responses have been made.

  - **Variable Ratio Schedule (VR)**: A procedure in which reinforcement comes after a number of responses that is randomized from one reinforcement to the next (ex. slot machines). The lower the number of responses required, the higher the response rate tends to be. Ratio schedules tend to produce very rapid responding, often with breaks of no responding just after reinforcement if a large number of responses is required for reinforcement.

**Operant Conditioning Chamber**

An operant conditioning chamber (also known as a *Skinner Box*) is a laboratory apparatus used in the experimental analysis of animal behavior. It was invented by Skinner while he was a graduate student at Harvard University. As used by Skinner, the box had a lever (for rats), or a disk in one wall (for pigeons). A press on this "manipulandum" could deliver food to the animal through an opening in the wall, and responses reinforced in this
way increased in frequency. By controlling this reinforcement together with discriminatory stimuli such as lights and tones, or punishments such as electric shocks, experimenters have used the operant box to study a wide variety of topics, including schedules of reinforcement, discriminatory control, delayed response ("memory"), punishment, and so on. By channeling research in these directions, the operant conditioning chamber has had a huge influence on course of research in animal learning and its applications. It enabled great progress on problems that could be studied by measuring the rate, probability, or force of a simple, repeatable response. However, it discouraged the study of behavioral processes not easily conceptualized in such terms—spatial learning, in particular, which is now studied in quite different ways, for example, by the use of the water maze.\[32]\n
**Cumulative Recorder**

The cumulative recorder makes a pen-and-ink record of simple repeated responses. Skinner designed it for use with the Operant chamber as a convenient way to record and view the rate of responses such as a lever press or a key peck. In this device, a sheet of paper gradually unrolls over a cylinder. Each response steps a small pen across the paper, starting at one edge; when the pen reaches the other edge, it quickly resets to the initial side. The slope of the resulting ink line graphically displays the rate of the response; for example, rapid responses yield a steeply sloping line on the paper, slow responding yields a line of low slope. The cumulative recorder was a key tool used by Skinner in his analysis of behavior, and it was very widely adopted by other experimenters, gradually falling out of use with the advent of the laboratory computer.\[citation needed]\n
Skinner's major experimental exploration of response rates, presented in his book with C. B. Ferster, *Schedules of Reinforcement*, is full of cumulative records produced by this device.\[36]\n
**Air Crib**

The air crib is an easily cleaned, temperature- and humidity-controlled enclosure intended to replace the standard infant crib.\[40]\n
Skinner invented the device to help his wife cope with the day-to-day tasks of child rearing. It was designed to make early childcare simpler (by reducing laundry, diaper rash, cradle cap, etc.), while allowing the baby to be more mobile and comfortable, and less prone to cry. Reportedly it had some success in these goals.\[41]\n
The air crib was a controversial invention. It was popularly mischaracterized as a cruel pen, and it was often compared to Skinner's operant conditioning chamber, commonly called the "Skinner Box." This association with laboratory animal experimentation discouraged its commercial success, though several companies attempted production.\[41][42]\n
A 2004 book by Lauren Slater, entitled *Opening Skinner's Box: Great Psychology Experiments of the Twentieth Century*\[43]\n
caused a stir by mentioning the rumors that Skinner had used his baby daughter, Deborah, in some of his experiments, and that she had subsequently committed suicide. Although Slater's book stated that the rumors were false, a reviewer in *The Observer* in March 2004 misquoted Slater's book as supporting
the rumors. This review was read by Deborah Skinner (now Deborah Buzan, an artist and writer living in London) who wrote a vehement riposte in *The Guardian*. [44]

**Teaching Machine**

The teaching machine, a mechanical invention to automate the task of programmed learning. The teaching machine was a mechanical device whose purpose was to administer a curriculum of programmed learning. The machine embodies key elements of Skinner’s theory of learning and had important implications for education in general and classroom instruction in particular. In one incarnation, the machine was a box that housed a list of questions that could be viewed one at a time through a small window. (See picture). There was also a mechanism through which the learner could respond to each question. Upon delivering a correct answer, the learner would be rewarded. Skinner advocated the use of teaching machines for a broad range of students (e.g., preschool aged to adult) and instructional purposes (e.g., reading and music). For example, one machine that he envisioned could teach rhythm. He wrote:

A relatively simple device supplies the necessary contingencies. The student taps a rhythmic pattern in unison with the device. "Unison" is specified very loosely at first (the student can be a little early or late at each tap) but the specifications are slowly sharpened. The process is repeated for various speeds and patterns. In another arrangement, the student echoes rhythmic patterns sounded by the machine, though not in unison, and again the specifications for an accurate reproduction are progressively sharpened. Rhythmic patterns can also be brought under the control of a printed score. [47] The instructional potential of the teaching machine stemmed from several factors: it provided automatic, immediate and regular reinforcement without the use of aversive control; the material presented was coherent, yet varied and novel; the pace of learning could be adjusted to suit the individual. As a result, students were interested, attentive, and learned efficiently by producing the desired behavior, "learning by doing." Teaching machines, though perhaps rudimentary, were not rigid instruments of instruction. They could be adjusted and improved based upon the students’ performance. For example, if a student made many incorrect responses, the machine could be reprogrammed to provide less advanced prompts or questions—the idea being that students acquire behaviors most efficiently if they make few errors. Multiple-choice formats were not well-suited for teaching machines because they tended to increase student mistakes, and the contingencies of reinforcement were relatively uncontrolled.
Not only useful in teaching explicit skills, machines could also promote the development of a repertoire of behaviors that Skinner called self-management. Effective self-management means attending to stimuli appropriate to a task, avoiding distractions, reducing the opportunity of reward for competing behaviors, and so on. For example, machines encourage students to pay attention before receiving a reward. Skinner contrasted this with the common classroom practice of initially capturing students’ attention (e.g., with a lively video) and delivering a reward (e.g., entertainment) before the students have actually performed any relevant behavior. This practice fails to reinforce correct behavior and actually counters the development of self-management. Skinner pioneered the use of teaching machines in the classroom, especially at the primary level. Today computers run software that performs similar teaching tasks, and there has been a resurgence of interest in the topic related to the development of adaptive learning systems. [49]

**Pigeon-guided Missile**

During World War II, the US Navy required a weapon effective against surface ships, such as the German *Bismarck* class battleships. Although missile and TV technology existed, the size of the primitive guidance systems available rendered automatic guidance impractical. To solve this problem, Skinner initiated Project Pigeon, [50][51] which was intended to provide a simple and effective guidance system. This system divided the nose cone of a missile into three compartments, with a pigeon placed in each. Lenses projected an image of distant objects onto a screen in front of each bird. Thus, when the missile was launched from an aircraft within sight of an enemy ship, an image of the ship would appear on the screen. The screen was hinged, such that pecks at the image of the ship would guide the missile toward the ship. [52]

Despite an effective demonstration the project was abandoned, and eventually more conventional solutions, such as those based on radar, became available. Skinner complained that "our problem was no one would take us seriously." [53] It seemed that few people would trust pigeons to guide a missile, no matter how reliable the system appeared to be. [54]

**Verbal Summator**

Early in his career Skinner became interested in "latent speech" and experimented with a device he called the "verbal summator." [55] This device can be thought of as an auditory version of the Rorschach inkblots. [55] When using the device, human participants listened to incomprehensible auditory "garbage" but often read meaning into what they heard. Thus, as with the Rorschach blots, the device was intended to yield overt behavior that projected subconscious thoughts. Skinner's interest in projective testing was brief, but he later used observations with the summator in creating his theory of verbal behavior. The device also led other researchers to invent new tests such as the tautophone test, the auditory apperception test, and the Azzageddi test. [56]
Verbal Behavior

Challenged by Alfred North Whitehead during a casual discussion while at Harvard to provide an account of a randomly provided piece of verbal behavior,[57] Skinner set about attempting to extend his then-new functional, inductive approach to the complexity of human verbal behavior.[58] Developed over two decades, his work appeared in the book Verbal Behavior. Although Noam Chomsky was highly critical of Verbal Behavior, he conceded that Skinner's "S-R psychology" was worth a review. (Behavior analysts reject the "S-R" characterization: operant conditioning involves the emission of a response which then becomes more or less likely depending upon its consequence—see above.) Verbal Behavior had an uncharacteristically cool reception, partly as a result of Chomsky's review, partly because of Skinner's failure to address or rebut any of Chomsky's criticisms.[60] Skinner's peers may have been slow to adopt the ideas presented in Verbal Behavior because of the absence of experimental evidence—unlike the empirical density that marked Skinner's experimental work.[61] However, in applied settings there has been a resurgence of interest in Skinner's functional analysis of verbal behavior. Skinner's views influenced education as well as psychology. Skinner argued that education has two major purposes: (1) to teach repertoires of both verbal and nonverbal behavior; and (2) to interest students in learning. He recommended bringing students’ behavior under appropriate control by providing reinforcement only in the presence of stimuli relevant to the learning task. Because he believed that human behavior can be affected by small consequences, something as simple as "the opportunity to move forward after completing one stage of an activity" can be an effective reinforcer (Skinner, 1961, p. 380). Skinner was convinced that, to learn, a student must engage in behavior, and not just passively receive information. (Skinner, 1961, p. 389).

Skinner believed that effective teaching must be based on positive reinforcement which is, he argued, more effective at changing and establishing behavior than punishment. He suggested that the main thing people learn from being punished is how to avoid punishment. For example, if a child is forced to practice playing an instrument, the child comes to associate practicing with punishment and thus learns to hate and avoid practicing the instrument. This view had obvious implications for the then widespread practice of rote learning and punitive discipline in education. The use of educational activities as punishment may induce rebellious behavior such as vandalism or absence.[63] Because teachers are primarily responsible for modifying student behavior, Skinner argued that teachers must learn effective ways of teaching. In The Technology of Teaching, Skinner has a chapter on why teachers fail (pages 93–113): He says that teachers have not been given an in-depth understanding of teaching and learning. Without knowing the science underpinning teaching, teachers fall back on procedures that work poorly or not at all, such as:

- using aversive techniques (which produce escape and avoidance and undesirable emotional effects);
- relying on telling and explaining ("Unfortunately, a student does not learn simply when he is shown or told." p. 103);
- failing to adapt learning tasks to the student's current level;
- failing to provide positive reinforcement frequently enough.
Skinner suggests that any age-appropriate skill can be taught. The steps are
1. Clearly specify the action or performance the student is to learn.
2. Break down the task into small achievable steps, going from simple to complex.
3. Let the student perform each step, reinforcing correct actions.
4. Adjust so that the student is always successful until finally the goal is reached.
5. Shift to intermittent reinforcement to maintain the student's performance.

Skinner's views on education are extensively presented in his book *The Technology of Teaching*. They are also reflected in Fred S. Keller's *Personalized System of Instruction* and Ogden R. Lindsley's *Precision Teaching*.

Skinner is popularly known mainly for his books *Walden Two* and *Beyond Freedom and Dignity*, (for which he made the cover of TIME Magazine).[64] The former describes a fictional "experimental community" in 1940s United States. The productivity and happiness of citizens in this community is far greater than in the outside world because the residents practice scientific social planning and use operant conditioning in raising their children.

*Walden Two*, like Thoreau's *Walden*, champions a lifestyle that does not support war, or foster competition and social strife. It encourages a lifestyle of minimal consumption, rich social relationships, personal happiness, satisfying work, and leisure.[66] In 1967, Kat Kinkade founded the Twin Oaks Community, using Walden Two as a blueprint. The community still exists and continues to use the Planner-Manager system and other aspects described in Skinner's book.

In *Beyond Freedom and Dignity*, Skinner suggests that a technology of behavior could help to make a better society. We would, however, have to accept that an autonomous agent is not the driving force of our actions. Skinner offers alternatives to punishment, and challenges his readers to use science and modern technology to construct a better society.

**Political Views**

Skinner's political writings emphasized his hopes that an effective and human science of behavioral control – a technology of human behavior – could help with problems as yet unsolved and often aggravated by advances in technology such as the atomic bomb. Indeed, one of Skinner's goals was to prevent humanity from destroying itself.[67] He saw political activity as the use of aversive or non-aversive means to control a population. Skinner favored the use of positive reinforcement as a means of control, citing Jean-Jacques Rousseau's novel *Emile: or, On Education* as an example of literature that "did not fear the power of positive reinforcement."[3]

Skinner's book, *Walden Two*, presents a vision of a decentralized, localized society, which applies a practical, scientific approach and behavioral expertise to deal peacefully with social problems. (For example, his views led him to oppose corporal punishment in schools, and he wrote a letter to the California Senate that helped lead it to a ban on spanking.[68]) Skinner's utopia is both a thought experiment and a rhetorical piece.
In *Walden Two*, Skinner answers the problem that exists in many utopian novels – "What is the Good Life?" The book's answer is a life of friendship, health, art, a healthy balance between work and leisure, a minimum of unpleasantness, and a feeling that one has made worthwhile contributions to a society in which resources are ensured, in part, by minimizing consumption. If the world is to save any part of its resources for the future, it must reduce not only consumption but the number of consumers.

Skinner described his novel as "my New Atlantis", in reference to Bacon's utopia.[69]

When Milton's Satan falls from heaven, he ends in hell. And what does he say to reassure himself? 'Here, at least, we shall be free.' And that, I think, is the fate of the old-fashioned liberal. He's going to be free, but he's going to find himself in hell.

One of Skinner's experiments examined the formation of superstition in one of his favorite experimental animals, the pigeon. Skinner placed a series of hungry pigeons in a cage attached to an automatic mechanism that delivered food to the pigeon "at regular intervals with no reference whatsoever to the bird's behavior." He discovered that the pigeons associated the delivery of the food with whatever chance actions they had been performing as it was delivered, and that they subsequently continued to perform these same actions.[70]

One bird was conditioned to turn counter-clockwise about the cage, making two or three turns between reinforcements. Another repeatedly thrust its head into one of the upper corners of the cage. A third developed a 'tossing' response, as if placing its head beneath an invisible bar and lifting it repeatedly. Two birds developed a pendulum motion of the head and body, in which the head was extended forward and swung from right to left with a sharp movement followed by a somewhat slower return.[71][72]

Skinner suggested that the pigeons behaved as if they were influencing the automatic mechanism with their "rituals", and that this experiment shed light on human behavior:

The experiment might be said to demonstrate a sort of superstition. The bird behaves as if there were a causal relation between its behavior and the presentation of food, although such a relation is lacking. There are many analogies in human behavior. Rituals for changing one's fortune at cards are good examples. A few accidental connections between a ritual and favorable consequences suffice to set up and maintain the behavior in spite of many unreinforced instances. The bowler who has released a ball down the alley but continues to behave as if she were controlling it by twisting and turning her arm and shoulder is another case in point. These behaviors have, of course, no real effect upon one's luck or upon a ball half way down an alley, just as in the present case the food would appear as often if the pigeon did nothing—or, more strictly speaking, did something else.[71]

Modern behavioral psychologists have disputed Skinner's "superstition" explanation for the behaviors he recorded. Subsequent research (e.g. Staddon and Simmelhag, 1971),
while finding similar behavior, failed to find support for Skinner's "adventitious reinforcement" explanation for it. By looking at the timing of different behaviors within the interval, Staddon and Simmelhag were able to distinguish two classes of behavior: the terminal response, which occurred in anticipation of food, and interim responses, that occurred earlier in the interfood interval and were rarely contiguous with food. Terminal responses seem to reflect classical (as opposed to operant) conditioning, rather than adventitious reinforcement, guided by a process like that observed in 1968 by Brown and Jenkins in their "autoshaping" procedures. The causation of interim activities (such as the schedule-induced polydipsia seen in a similar situation with rats) also cannot be traced to adventitious reinforcement and its details are still obscure (Staddon, 1977)

5.4. Gagné's Hierarchy of Learning
In 1956, the American educational psychologist Robert M. Gagné proposed a system of classifying different types of learning in terms of the degree of complexity of the mental processes involved. He identified eight basic types, and arranged these in the hierarchy shown in Figure 1. According to Gagné, the higher orders of learning in this hierarchy build upon the lower levels, requiring progressively greater amounts of previous learning for their success. The lowest four orders tend to focus on the more behavioural aspects of learning, while the highest four focus on the more cognitive aspects.

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<th>Increasing complexity</th>
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<td>7: Rule learning</td>
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Gagné's hierarchy of learning:
Let us now take a closer look at Gagné's eight categories of learning.

1. **Signal Learning.** This is the simplest form of learning, and consists essentially of the classical conditioning first described by the behavioral psychologist Pavlov. In this, the subject is 'conditioned' to emit a desired response as a result of a stimulus that would not normally produce that response. This is done by first exposing the subject to the chosen stimulus (known as the conditioned stimulus) along with another stimulus (known as the unconditioned stimulus) which produces the desired response naturally; after a certain number of repetitions of the double stimulus, it is found that the subject emits the desired response when exposed to the conditioned stimulus on its own. The applications of classical conditioning in facilitating human learning are, however, very limited.

2. **Stimulus-response learning.** This somewhat more sophisticated form of learning, which is also known as operant conditioning, was originally developed by
Skinner. It involves developing desired stimulus-response bonds in the subject through a carefully-planned reinforcement schedule based on the use of 'rewards' and 'punishments'. Operant conditioning differs from classical conditioning in that the reinforcing agent (the 'reward' or 'punishment') is presented after the response. It is this type of conditioning that forms the basis of programmed learning in all its various manifestations.

3. **Chaining.** This is a more advanced form of learning in which the subject develops the ability to connect two or more previously-learned stimulus-response bonds into a linked sequence. It is the process whereby most complex psychomotor skills (e.g. riding a bicycle or playing the piano) are learned.

4. **Verbal association.** This is a form of chaining in which the links between the items being connected are verbal in nature. Verbal association is one of the key processes in the development of language skills.

5. **Discrimination learning.** This involves developing the ability to make appropriate (different) responses to a series of similar stimuli that differ in a systematic way. The process is made more complex (and hence more difficult) by the phenomenon of interference, whereby one piece of learning inhibits another. Interference is thought to be one of the main causes of forgetting.

6. **Concept learning.** This involves developing the ability to make a consistent response to different stimuli that form a common class or category of some sort. It forms the basis of the ability to generalize, classify etc.

7. **Rule learning.** This is a very-high-level cognitive process that involves being able to learn relationships between concepts and apply these relationships in different situations, including situations not previously encountered. It forms the basis of the learning of general rules, procedures, etc.

8. **Problem solving.** This is the highest level of cognitive process according to Gagné. It involves developing the ability to invent a complex rule, algorithm or procedure for the purpose of solving one particular problem, and then using the method to solve other problems of a similar nature.

5.5. **Gestalt Theory (Wertheimer)**

Along with Kohler and Kafka, Max Wertheimer was one of the principal proponents of Gestalt theory which emphasized higher-order cognitive processes in the midst of behaviorism. The focus of Gestalt theory was the idea of “grouping”, i.e., characteristics of stimuli causes us to structure or interpret a visual field or problem in a certain way (Wertheimer, 1922). The primary factors that determine grouping were: (1) proximity - elements tend to be grouped together according to their nearness, (2) similarity - items similar in some respect tend to be grouped together, (3) closure - items are grouped together if they tend to complete some entity, and (4) simplicity - items will be organized into simple figures according to symmetry, regularity, and smoothness. These factors were called the laws of organization and were explained in the context of perception and problem-solving.

Wertheimer was especially concerned with problem-solving. Wertheimer (1959) provides a Gestalt interpretation of problem-solving episodes of famous scientists (e.g., Galileo,
Einstein) as well as children presented with mathematical problems. The essence of successful problem-solving behavior according to Wertheimer is being able to see the overall structure of the problem: "A certain region in the field becomes crucial, is focused; but it does not become isolated. A new, deeper structural view of the situation develops, involving changes in functional meaning, the grouping, etc. of the items. Directed by what is required by the structure of a situation for a crucial region, one is led to a reasonable prediction, which like the other parts of the structure, calls for verification, direct or indirect. Two directions are involved: getting a whole consistent picture, and seeing what the structure of the whole requires for the parts." (p 212).

Application
Gestalt theory applies to all aspects of human learning, although it applies most directly to perception and problem-solving. The work of Gibson was strongly influenced by Gestalt theory.

Example
The classic example of Gestalt principles provided by Wertheimer is children finding the area of parallelograms. As long as the parallelograms are regular figures, a standard procedure can be applied (making lines perpendicular from the corners of the base). However, if a parallelogram with a novel shape or orientation is provided, the standard procedure will not work and children are forced to solve the problem by understanding the true structure of a parallelogram (i.e., the figure can be bisected anywhere if the ends are joined).

Principles
1. The learner should be encouraged to discover the underlying nature of a topic or problem (i.e., the relationship among the elements).
2. Gaps, incongruities, or disturbances are an important stimulus for learning

Instruction should be based upon the laws of organization: proximity, closure, similarity and simplicity

5.6. Jerome Seymour Bruner Theory
(October 1, 1915 – June 5, 2016) was an American psychologist who made significant contributions to human cognitive psychology and cognitive learning theory in educational psychology. Bruner was a senior research fellow at the New York University School of Law.[1] He received a B.A. in 1937 from Duke University and a Ph.D. from Harvard University in 1941.[2][3][4][5] A Review of General Psychology survey, published in 2002, ranked Bruner as the 28th most cited psychologist of the 20th century.

Education and Early Life
Bruner was born blind (due to cataracts) on October 1, 1915 in New York City, to Herman and Rose Bruner, who were Polish Jewish immigrants.[7][8] An operation at age 2 restored his vision. He received a bachelor's degree in psychology, in 1937 from Duke, and went on to earn a master's degree in psychology in 1939 and then a doctorate in
psychology in 1941 from Harvard.[2] In 1939, Bruner published his first psychological article on the effect of thymus extract on the sexual behavior of the female rat.[9] During World War II, Bruner served on the Psychological Warfare Division of the Supreme Headquarters Allied Expeditionary Force committee under General Dwight D. Eisenhower, researching social psychological phenomena.[7][10]

**Career and Research**

In 1945 Bruner returned to Harvard as a psychology professor and was heavily involved in research relating to cognitive psychology and educational psychology. In 1970 Bruner left Harvard to teach at the University of Oxford in the United Kingdom. He returned to the United States in 1980 to continue his research in developmental psychology. In 1991 Bruner joined the faculty at New York University.

As an adjunct professor at NYU School of Law, Bruner studied how psychology affects legal practice. During his career, Bruner was awarded honorary doctorates from Yale University, Columbia University, the Sorbonne, the ISPA Institute Universitário, as well as colleges and universities in such locations as Berlin and Rome, and was a Fellow of the American Academy of Arts and Sciences.[5] He turned 100 in October 2015[11] and died on June 5, 2016.[4][12]

**Cognitive Psychology**

*Main article: Cognitive Psychology*

Bruner is one of the pioneers of cognitive psychology in the United States, which began through his own early research on sensation and perception as being active, rather than passive processes.

In 1947 Bruner published his study *Value and Need as Organizing Factors in Perception*, in which poor and rich children were asked to estimate the size of coins or wooden disks the size of American pennies, nickels, dimes, quarters and half-dollars. The results showed that the value and need the poor and rich children associated with coins caused them to significantly overestimate the size of the coins, especially when compared to their more accurate estimations of the same size disks.[13]

Similarly, another study conducted by Bruner and Leo Postman showed slower reaction times and less accurate answers when a deck of playing cards reversed the color of the suit symbol for some cards (e.g. red spades and black hearts).[14] These series of experiments issued in what some called the 'New Look' psychology, which challenged psychologists to study not just an organism's response to a stimulus, but also its internal interpretation.[7] After these experiments on perception, Bruner turned his attention to the actual cognitions that he had indirectly studied in his perception studies.

In 1956 Bruner published the book *A Study of Thinking*, which formally initiated the study of cognitive psychology. Soon afterwards Bruner helped found the Harvard Center of Cognitive Studies. After a time, Bruner began to research other topics in psychology,
but in 1990 he returned to the subject and gave a series of lectures, later compiled into the book *Acts of Meaning*. In these lectures, Bruner refuted the computer model for studying the mind, advocating a more holistic understanding of the mind and its cognitions.

**Developmental Psychology**

Beginning around 1967 Bruner turned his attention to the subject of developmental psychology and studied the way children learn. He coined the term "scaffolding" to describe the way children often build on the information they have already mastered. In his research on the development of children (1966) Bruner proposed three modes of representation: enactive representation (action-based), iconic representation (image-based), and symbolic representation (language-based). Rather than neatly delineated stages, the modes of representation are integrated and only loosely sequential as they "translate" into each other. Symbolic representation remains the ultimate mode, for it "is clearly the most mysterious of the three."

Bruner's theory suggests it is efficacious, when faced with new material, to follow a progression from enactive to iconic to symbolic representation; this holds true even for adult learners. A true instructional designer, Bruner's work also suggests that a learner (even of a very young age) is capable of learning any material so long as the instruction is organized appropriately, in sharp contrast to the beliefs of Piaget and other stage theorists. (Driscoll, Marcy). Like Bloom's Taxonomy, Bruner suggests a system of coding in which people form a hierarchical arrangement of related categories. Each successively higher level of categories becomes more specific, echoing Benjamin Bloom's understanding of knowledge acquisition as well as the related idea of instructional scaffolding.

In accordance with this understanding of learning, Bruner proposed the spiral curriculum, a teaching approach in which each subject or skill area is revisited at intervals, at a more sophisticated level each time. First there is basic knowledge of a subject, then more sophistication is added, reinforcing principles that were first discussed. This system is used in China and India. Bruner's spiral curriculum, however, draws heavily from evolution to explain how to learn better and thus it drew criticism from conservatives. In the United States classes are split by grade—life sciences in 9th grade, chemistry in 10th, physics in 11th. The spiral teaches life sciences, chem., physics all in one year, then two subjects, then one, then all three again to understand how they mold together.\[15\] Bruner also believes learning should be spurred by interest in the material rather than tests or punishment, since one learns best when they find the knowledge they are obtaining appealing.

**Educational Psychology**

While Bruner was at Harvard he published a series of works about his assessment of current educational systems and ways that education could be improved. In 1961 he published the book *Process of Education*. Bruner also served as a member of the Educational Panel of the President's Science Advisory Committee during the presidencies of John F. Kennedy and Lyndon Johnson. Referencing his overall view that education should not focus merely on memorizing facts, Bruner wrote in *Process of Education* that
"knowing how something is put together is worth a thousand facts about it." From 1964–1996 Bruner sought to develop a complete curriculum for the educational system that would meet the needs of students in three main areas which he called Man: A Course of Study. Bruner wanted to create an educational environment that would focus on (1) what was uniquely human about human beings, (2) how humans got that way and (3) how humans could become more so.[9] In 1966 Bruner published another book relevant to education, Towards a Theory of Instruction, and then in 1973, another book, The Relevance of Education. Finally, in 1996, in The Culture of Education, Bruner reassessed the state of educational practices three decades after he had begun his educational research. Bruner was also credited with helping found the Head Start early childcare program.[16] Bruner was deeply impressed by his 1995 visit to the preschools of Reggio Emilia and has established a collaborative relationship with them to improve educational systems internationally. Equally important was the relationship with the Italian Ministry of Education which officially recognized the value of this innovative experience.

Language Development
In 1972 Bruner was appointed Watts Professor of Experimental Psychology at the University of Oxford, where he remained until 1980. In his Oxford years Bruner focused on early language development. Rejecting the natives account of language acquisition proposed by Noam Chomsky, Bruner offered an alternative in the form of an integrationist or social integrationist theory of language development. In this approach, the social and interpersonal nature of language was emphasized, appealing to the work of philosophers such as Ludwig Wittgenstein, John L. Austin and John Searle for theoretical grounding.[citation needed] Following Lev Vygotsky the Russian theoretician of socio-cultural development, Bruner proposed that social interaction plays a fundamental role in the development of cognition in general and of language in particular. He emphasized that children learn language in order to communicate, and, at the same time, they also learn the linguistic code. Meaningful language is acquired in the context of meaningful parent-infant interaction, learning “scaffolded” or supported by the child’s Language Acquisition Support System (LASS).

At Oxford Bruner worked with a large group of graduate students and post-doctoral fellows to understand how young children manage to crack the linguistic code, among them Alison Garton, Alison Gopnik, Magda Kalmar (hu:Kalmár Magda (pszichológus)), Alan Leslie, Andrew Meltzoff, Anat Ninio, Roy Pea, Susan Sugarman,[17] Michael Scarify, Marian Sigmund,[18] Kathy Sylva and many others. Much emphasis was placed on employing the then-revolutionary method of videotaped home-observations, Bruner showing the way to a new wave of researchers to get out of the laboratory and take on the complexities of naturally occurring events in a child’s life. This work was published in a large number of journal articles, and in 1983 Bruner published a summary in the book Child’s talk: Learning to Use Language.

This decade of research established Bruner at the helm of the integrationist approach to language development, exploring such themes as the acquisition of communicative intents and the development of their linguistic expression, the interactive context of
language use in early childhood, and the role of parental input and scaffolding behavior in the acquisition of linguistic forms. This work rests on the assumptions of a social constructivist theory of meaning according to which meaningful participation in the social life of a group as well as meaningful use of language involve an interpersonal, intersubjective, collaborative process of creating shared meaning. The elucidation of this process became the focus of Bruner’s next period of work.

**Narrative Construction of Reality**
In 1980 Bruner returned to the United States, taking up the position of professor at the New School for Social Research in New York City in 1981. For the next decade, he worked on the development of a theory of the narrative construction of reality, culminating in several seminal publications. His book *Actual Minds, Possible Worlds* has been cited by over 16,100 scholarly publications, making it one of the most influential works of the 20th century.

**Legal Psychology.**
In 1991 Bruner arrived at NYU as a visiting professor to do research and to found the Colloquium on the Theory of Legal Practice. The goal of this institution is to "study how law is practiced and how its practice can be understood by using tools developed in anthropology, psychology, linguistics, and literary theory.

**5.7. Ausubel's Learning Theory**
**David Paul Ausubel** was an American psychologist who’s most significant contribution to the fields of educational psychology, cognitive science, and science education. Ausubel believed that understanding concepts, principles, and ideas are achieved through deductive reasoning. Similarly, he believed in the idea of meaningful learning as opposed to rote memorization. The most important single factor influencing learning is what the learner already knows. This led Ausubel to develop an interesting theory of meaningful learning and advance organizers.

**Learning Theory**
Ausubel's believes that learning of new knowledge relies on what is already known. That is, construction of knowledge begins with our observation and recognition of events and objects through concepts we already have. We learn by constructing a network of concepts and adding to them.

Ausubel also stresses the importance of reception rather than discovery learning, and meaningful rather than rote learning. He declares that his theory applies only to reception learning in school settings. He didn’t say, however, that discovery learning doesn’t work; but rather that it was not efficient. In other words, Ausubel believed that understanding concepts, principles, and ideas are achieved through deductive reasoning.
Ausubel was influenced by the teachings of Jean Piaget. Similar to Piaget’s ideas of conceptual schemes, Ausubel related this to his explanation of how people acquire knowledge.

**Meaningful learning**
Ausebel’s theory also focuses on meaningful learning. According to his theory, to learn meaningfully, individuals must relate new knowledge to relevant concepts they already know. New knowledge must interact with the learner’s knowledge structure. Meaningful learning can be contrasted with rote learning. he believed in the idea of meaningful learning as opposed to rote memorization. The latter can also incorporate new information into the pre-existing knowledge structure but without interaction. Rote memory is used to recall sequences of objects, such as phone numbers. However, it is of no use to the learner in understanding the relationships between the objects. 2

Because meaningful learning involves recognition of the links between concepts, it has the privilege of being transferred to long-term memory. The most crucial element in meaningful learning is how the new information is integrated into the old knowledge structure. Accordingly, Ausubel believes that knowledge is hierarchically organized; that new information is meaningful to the extent that it can be related (attached, anchored) to what is already known.

**The rote-meaningful learning continuum showing the requirements of meaningful learning**

**Advance Organizers**
Ausubel advocates the use of advance organizers as a mechanism to help to link new learning material with existing related ideas. Advance organizers are helpful in the way that they help the process of learning when difficult and complex material is introduced. This is satisfied through two conditions:

1. The student must process and understand the information presented in the organizer--this increases the effectiveness of the organizer itself. 3
2. The organizer must indicate the relations among the basic concepts and terms that will be used

Ausubel’s theory of advance organizers fall into two categories: comparative and expository

**Comparative Organizers**
The main goal of comparative organizers is to activate existing schemas and is used as reminders to bring into the working memory of what you may not realize are relevant. A comparative Organizer is also used both to integrate as well as discriminate. It “integrates new ideas with basically similar concepts in cognitive
structure, as well as increase discriminability between new and existing ideas which are essentially different but confusable similar”

**Expository Organizers**

“In contrast, expository organizers provide new knowledge that students will need to understand the upcoming information”. Expository organizers are often used when the new learning material is unfamiliar to the learner. They often relate what the learner already knows with the new and unfamiliar material—this in turn is aimed to make the unfamiliar material more plausible to the learner.

**Ausubel Learning Model**

Ausubel believed that learning proceeds in a top-down or deductive manner. Ausubel's theory consists of three phases. The main elements of ausubel teaching method are shown below in the table

### Ausubel’s Model of Meaningful Learning

<table>
<thead>
<tr>
<th>Phase One</th>
<th>Phase Two</th>
<th>Phase Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance Organizer</td>
<td>Presentation of Learning task or Material</td>
<td>Strengthening Cognitive Organization</td>
</tr>
<tr>
<td>Clarify aim of the lesson</td>
<td>Make the organization of the new material explicit</td>
<td>Relate new information to advance organizer</td>
</tr>
<tr>
<td>Present the lesson</td>
<td>Make logical order of learning material explicit</td>
<td>Promote active reception learning</td>
</tr>
<tr>
<td>Relate organizer to students’ prior knowledge</td>
<td>Present material in terms of basic similarities and differences by using examples, and engage students in meaningful learning activities</td>
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5.8. **Formative Classroom Assessment and Benjamin S. Bloom: Theory**

Although much recent attention has focused on gaps in the achievement of different groups of students, the problem has been with us for decades. This paper presents the problem as one of reducing variation in students’ achievement, and reviews the work of renowned educator Benjamin Bloom on this problem. Bloom argued that to reduce variation in students’ achievement and to have all students learn well, we must increase variation in instructional approaches and learning time. The key element in this effort was well constructed, formative classroom assessments. Bloom outlined a specific strategy for using formative classroom assessments to guide teachers in differentiating their instruction and labeled it “mastery learning.” This paper describes Bloom’s work, presents the essential elements of mastery learning, explains common misinterpretations, and describes the results of research on its effects.

**Formative Classroom Assessment and Benjamin S. Bloom: Theory**

Achievement gaps among different groups of students have concerned government and educational leaders for many years. In the 1960s, President Lyndon Johnson’s “War on
Poverty” focused directly on inequalities in the educational achievement of economically disadvantaged students and their more advantaged counterparts. The Economic Opportunity Act (EOA) of 1964, which established the Head Start program, and the Elementary and Secondary Education Act (ESEA) of 1965, which created the Title I and Follow Through programs, were specific attempts to address these gaps in educational attainment.

More recently, the No Child Left Behind (NCLB) legislation (U.S. Congress, 2001) revived these concerns. The law requires schools to report achievement results separately for various poverty, ethnicity, language, and disability subgroups. Not only must schools identify any achievement gaps among these different student subgroups, they also must take specific steps to close them.

Over the years educational researchers have learned a lot about reducing these achievement disparities. Yet because of our tendency in education today to focus only on “what’s new,” a lot of that important knowledge is being neglected. Instead of building on what we already know, many modern proposals for closing achievement gaps simply rename well-established principles, adding to the tangled thicket of terminology that confounds progress in education. To succeed in our efforts to close achievement gaps and to reach our goal of helping all students learn well, we need instead to recognize and extend this hard-earned knowledge base.

Researchers’ Views
Researchers do their best to view problems in their simplest and most basic form. From a researcher’s perspective, therefore, achievement gaps are simply matters of “variation”: students vary in their levels of achievement. Some students learn excellently in school and reach high levels of achievement, while others learn less well and attain only modest levels. Whenever we measure two or more students’ achievement, we also measure this “variation.”

Researchers design studies to “explain” variation. They make educated guesses, called “hypotheses,” about what factors contribute to the differences among individuals. Then they manipulate those factors in carefully planned investigations to determine the effects. When they find a relationship between the factors that they manipulate and differences in outcomes, they succeed in their efforts to “explain” variation.

One of the early researchers concerned with explaining variation in student achievement was Benjamin S. Bloom. In the early 1960s, Bloom’s studies focused on individual differences, especially in students’ school learning. While he recognized that many factors outside of school affect student learning (Bloom, 1964), his investigations showed that teachers have potentially strong influence as well. In his observations of classrooms, Bloom noted that most teachers included little variation in their instructional practices. The majority taught all students in much the same way and provided all with the same amount of time to learn. The few students for whom the instructional methods and time were ideal learned excellently. The largest number of students for whom the methods and
time were only moderately appropriate learned less well. And students for whom the instruction and time were inappropriate due to differences in their backgrounds or learning styles, learned very little. In other words, little variation in the teaching resulted in great variation in student learning. Under these conditions the pattern of student achievement was similar to the normal curve distribution shown in Figure 1. Distribution of Achievement in Traditional Classrooms

To attain better results and reduce this variation in student achievement, Bloom reasoned that we would have to increase variation in the teaching. That is, because students varied in their learning styles and aptitudes, we must diversify and differentiate instruction to better meet their individual learning needs. The challenge was to find practical ways to do this within the constraints of group-based classrooms so that all students learn well.

In searching for such a strategy, Bloom drew primarily from two sources of evidence. First he considered the ideal teaching and learning situation in which an excellent tutor is paired with each student. He was particularly influenced by the work of early pioneers in individualized instruction, especially Washburn (1922) and his Winnetka Plan, and Morrison (1926) and his University of Chicago Laboratory School experiments. In examining this evidence, Bloom tried to determine what critical elements in one-to-one tutoring and individualized instruction could be transferred to group-based classroom settings.

Second, Bloom looked at studies of the learning strategies of academically successful students, especially the work of Dollard and Miller (1950). From this research he tried to identify the activities of high achieving students in group-based classrooms that distinguish them from their less successful classmates. Bloom believed it was reasonable for teachers to organize the concepts and skills they wanted students to learn into instructional units. He also considered valuable for teachers to assess student learning at the end of each unit. But he found that most teachers’ classroom assessments did little more than show for whom their initial instruction was and was not appropriate.

A far better approach, according to Bloom, would be for teachers to use their classroom assessments as learning tools, and then to follow those assessments with a feedback and corrective procedure. In other words, instead of using assessments only as evaluation devices that mark the end of each unit, Bloom recommended using them as part of the instructional process to diagnose individual learning difficulties (feedback) and to prescribe remediation procedures (correctives).

This is precisely what takes place when an excellent tutor works with an individual student. If the student makes an error, the tutor first points out the error (feedback), and then follows up with further explanation and clarification (correctives) to ensure the student’s understanding. Similarly, academically successful students typically follow up the mistakes they make on quizzes and assessments. They ask the teacher about the items they missed, look up the answer in the textbook or other resources, or rework the problem or task so that errors are not repeated.
Bloom’s Mastery Learning

Benjamin Bloom then outlined a specific instructional strategy to make use of this feedback and corrective procedure, labeling it “learning for mastery” (Bloom, 1968), and later shortening the name to simply “mastery learning” (Bloom, 1971). With this strategy, teachers first organize the concepts and skills they want students to learn into instructional units that typically involve about a week or two of instructional time. Following initial instruction on the unit, teachers administer a brief “formative” assessment based on the unit’s learning goals. Instead of signifying the end of the unit, however, this formative assessment’s purpose is to give students information, or feedback, on their learning. It helps students identify what they have learned well to that point and what they need to learn better (Bloom, Hastings, & Madams, 1971).

Paired with each formative assessment are specific “corrective” activities for students to use in correcting their learning difficulties. Most teachers match these “correctives” to each item or set of prompts within the assessment so that students need work on only those concepts or skills not yet mastered. In other words, the correctives are “individualized.” They may point out additional sources of information on a particular topic, such as page numbers in the textbook or workbook where the topic is discussed. They may identify alternative learning resources such as different textbooks, learning kits, alternative materials, CDs, videos, or computerized instructional lessons. Or they may simply suggest sources of additional practice, such as study guides, independent or guided practice activities, or collaborative group activities.

With the feedback and corrective information gained from a formative assessment, each student has a detailed prescription of what more needs to be done to master the concepts or skills from the unit. This “just-in-time” correction prevents minor learning difficulties from accumulating and becoming major learning problems. It also gives teachers a practical means to vary and differentiate their instruction in order to better meet students’ individual learning needs. As a result, many more students learn well, master the important learning goals in each unit, and gain the necessary prerequisites for success in subsequent units (Bloom, Madams, & Hastings, 1981).

When students complete their corrective activities after a class period or two, Bloom recommended they take a second formative assessment. This second, “parallel” assessment covers the same concepts and skills as the first, but is composed of slightly different problems or questions, and serves two important purposes. First, it verifies whether or not the correctives were successful in helping students overcome their individual learning difficulties. Second, it offers students a second chance at success and, hence, has powerful motivational value.

Some students, of course, will perform well on the first assessment, demonstrating that they’ve mastered the unit concepts and skills. The teacher’s initial instruction was highly appropriate for these students and they have no need of corrective work. To ensure their continued learning progress, Bloom recommended these students be provided with special “enrichment” or “extension” activities to broaden their learning experiences. Such
activities often are self-selected by students and might involve special projects or reports, academic games, or a variety of complex, problem-solving tasks. Figure 2 illustrates this instructional sequence.

The Mastery Learning Instructional Process Through this process of formative classroom assessment, combined with the systematic correction of individual learning difficulties, Bloom believed all students could be provided with a more appropriate quality of instruction than is possible under more traditional approaches to teaching. As a result, nearly all might be expected to learn well and truly master the unit concepts or learning goals (Bloom, 1976). This, in turn, would drastically reduce the variation in students’ achievement levels, eliminate achievement gaps, and yield a distribution of achievement.
PSYCHOLOGICAL FOUNDATIONS OF SCIENCE EDUCATION-II

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Reviewed by: Arshad Mahmood
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INTRODUCTION

This Unit explains constructivist view of acquiring knowledge in science and its impacts on science education. Constructivism is a very influent theory of science education. This is a theory about how knowledge is acquired and constructed. The constructivist epistemology asserts that the only tools available to a knower are the senses.

In this unit we have traced the origin of constructivist view of knowledge and discussed the philosophical basis of this theory. A brief discussion on variety of constructivism has also been included in this account. Types of constructivists are also discussed. Piagetian theory of cognitive development is also included. Apart from it Bandera’s Social Learning theory is also a part of this unit.

OBJECTIVES

After reading this unit you will be able to:
1. understand the concept of constructivism.
2. concept clearance about learning and cognitive development theories
6.1. Constructivism as a Referent in Teaching Science

Why is it, in educational settings, we rarely talk about how students learn? Why aren't teachers using how students learn as a guide to their teaching practices? These questions seem almost too absurd to ask; but think, when was the last time you spoke to colleagues about how students learn? Do you observe learning in your classroom? What does it look like? These are a few of the questions that we have begun to ask ourselves and our teaching colleagues. One way to make sense of how students learn is through constructivism. Constructivism is a word used frequently by science educators lately. It is used increasingly as a theoretical rationale for research and teaching. Many current reform efforts also are associated with the notion of constructivism. But what exactly is constructivism and how can it be useful to the practicing teacher? Constructivism is an epistemology, a theory of knowledge used to explain how we know what we know. We believe that a constructivist epistemology is useful to teachers if used as a referent; that is, as a way to make sense of what they see, think, and do. Our research indicates that teacher's beliefs about how people learn (their personal epistemology), whether verbalized or not, often help them make sense of, and guide, their practice. The epistemology that is dominant in most educational settings today is similar to objectivism. That is to say, most researchers view knowledge as existing outside the bodies of cognizing beings, as beings separate from knowing and knower. Knowledge is "out there," residing in books, independent of a thinking being. Science is then conceptualized as a search for truths, a means of discovering theories, laws, and principles associated with reality. Objectivity is a major component of the search for truths which underlie reality; learners are encouraged to view objects, events, and phenomenon with an objective mind, which is assumed to be separate from cognitive processes such as imagination, intuition, feelings, values, and beliefs (Johnson, 1987). As a result, teachers implement a curriculum to ensure that students cover relevant science content and have opportunities to learn truths which usually are documented in bulging textbooks.

The constructivist epistemology asserts that the only tools available to a knower are the senses. It is only through seeing, hearing, touching, smelling, and tasting that an individual interacts with the environment. With these messages from the senses the individual builds a picture of the world. Therefore, constructivism asserts that knowledge resides in individuals; that knowledge cannot be transferred intact from the head of a teacher to the heads of students. The student tries to make sense of what is taught by trying to fit it with his/her experience. Consequently, words are not containers whose meanings are in the words itself, they are based on the constructions of individuals. We can communicate because individual's meanings of words only have to be compatible with the meanings given by others. If a situation occurred in which your meaning of a word no longer sufficed, you could change the meaning of the word. Using constructivism as a referent, teachers often use problem-solving as a learning strategy; where learning is defined as adaptations made to fit the world they experience. That is, to learn, a person's existing conceptions of the world must be unreliable, enviable. When one's conceptions of the world are enviable one tries to make sense out of the situation based on what is already known (i.e. Prior knowledge is used to make sense of data
perceived by the senses). Other persons are part of our experiential world, thus, others are important for meaning making. "Others" are so important for constructivists that cooperative learning is a primary teaching strategy. A cooperative learning strategy allows individuals to test the fit of their experiential world with a community of others. Others help to constrain our thinking. The interactions with others cause perturbations, and by resolving the perturbations individuals make adaptations to fit their new experiential world. Experience involves an interaction of an individual with events, objects, or phenomenon in the universe; an interaction of the senses with things, a personal construction which fits some of the external reality but does not provide a match. The senses are not conduits to the external world through which truths are conducted into the body. Objectivity is not possible for thinking beings. Accordingly, knowledge is a construction of how the world works, one that is viable in the sense that it allows an individual to pursue particular goals. Thus, from a constructivist perspective, science is not the search for truth. It is a process that assists us to make sense of our world. Using a constructivist perspective, teaching science becomes more like the science that scientists do it is an active, social process of making sense of experiences, as opposed to what we now call "school science." Indeed, actively engaging students in science (we have all heard the call for "hands-on, minds-on science") is the goal of most science education reform. It is an admirable goal, and using constructivism as a referent can possibly assist in reaching that goal. Driver (1989) has used a constructivist epistemology as a referent in her research on children's conceptions of science. Children's prior knowledge of phenomena from a scientific point of view differs from the interpretation children construct; children construct meanings that fit their experience and expectations. This can lead children to oftentimes construct meanings different from what was intended by a teacher. Teachers that make sense of teaching from an objectivist perspective fail to recognize that students solve this cognitive conflict by separating school science from their own life experiences. In other words, students distinguish between scientific explanations and their "real world" explanations (the often cited example—that forces are needed to keep a ball in motion versus Newton's explanation is one such example). Children's conceptions are their constructions of reality, ones that are viable in the sense that they allow a child to make sense of his/her environment. By using a constructivist epistemology as a referent teachers can become more sensitive to children's prior knowledge and the processes by which they make sense of phenomena. The teaching practices of two teachers at City Middle School may best illustrate how practice can be influenced by making sense of teaching and learning from constructivist-and objectivist oriented perspective. To Bob, science was a body of knowledge to be learned. His job was to "give out" what he (and the textbook) knew about science to his students. Thus the learning environment Bob tried to maintain in his classroom facilitated this transfer of knowledge; the desks were neatly in rows facing Bob and the blackboard.

Lectures and assignments from the text were given to students. Bob tried to keep students quiet and working all during the class period to ensure that all students could "absorb" the science knowledge efficiently. Another consequence of Bob's notion of teaching and learning was his belief that he had so much cover that he had no time for laboratory activities. Let's look at an example that typifies Bob's teaching style. Bob's sixth grade
students were to complete a worksheet that "covered" the concept of friction. After the students completed the worksheet, Bob went over the answers so the students could have the correct answers for the test later in the week. From a constructivist perspective, what opportunities did Bob's students have to relate the concept of friction to their own experiences? Were these opportunities in Bob's lesson plan to negotiate meanings and build a consensus of understanding? Bob spent one class period covering the concept of friction: is that sufficient time for students to learn a concept with understanding? On the other hand, John made sense of teaching and learning from a constructivist perspective. John's classes were student-centered and activity-based. Typically in his high school classes, John introduced students to different science topics with short lectures, textbook readings, and confirmatory laboratories. After the introduction John would ask students what interested them about the topic and encouraged them to pursue and test these ideas. Students usually divided themselves into groups and then, conducted a library research, formulated questions/problems, and procedures to test the questions/problems. In other words, the students were acting as scientists in the classroom. Like Bob, John taught a sixth grade class previously, and also taught students about friction. Included in John's lessons were activities to "get the students involved." Students rubbed their hands together with and without a lubricant so that they could see the purpose of motor oil in engines. The students conducted experiments with bricks to learn about different types of friction, and even watched The Flintstones in class to point out friction and what would really happen (i.e. Fred would burn his feet stopping the car, etc.) John spent two weeks teaching his unit on friction. Were John's students given opportunities to make sense of the concept of friction?

Constructivism as an epistemology is briefly outlined and its usefulness for teachers using it as referent is described. The beliefs and knowledge about learning of two teachers is contrasted in order to compare a constructivist approach to learning and an objectivist approach. Evidence that one of the teachers uses constructivism as a referent is highlighted by his approach to teaching, arrangement of his classroom and questioning techniques. Finally two major challenges faced by South African teachers that would want to use constructivism as a referent are discussed with some suggestions as to how these challenges can be overcome in order to move from an objectivist approach to a constructivist approach.

6.2 Types of Constructivism

Radical and Social Constructivism
Constructivist ideas fall into a couple of not-always-distinct camps. The first camp, which finds its extreme expression in the radical constructism of Ernst von Glaserfeld, revolves around the idea that each individual constructs reality for him or herself. Radical Constructivism puts forward two main claims (von Glasersfeld 1989: 162):

"(a) Knowledge is not passively received but actively built up by the cognizing subject; (b) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality."
In other words, all experience is subjective, filtered through the prism of individual biases, experiences, and sense perceptions. The mind simply organizes this stuff into something we call "reality."

An alternate camp, generally referred to as social constructivism, emphasizes the role of culture and context in developing personal and shared interpretations of reality. It emerges largely from the work of Piaget, Vygotsky, Bruner, and Bandera. It shares with radical constructivism the idea that reality is constructed, but to social constructivists this construction does not exist prior to its social invention. Knowledge is a social product, and learning a social process, and meaning is an agreement shaped by social patterns and the assumptions encapsulated in language.

One particularly influential social constructivist-based theory is Vygotsky's idea of the Zone of Proximal Development. The ZPD describes the difference between what a person can learn on his or her own, and what that person can learn when learning is facilitated by someone with greater expertise. The idea of well-timed instructional interventions, operating within an individual's ZPD, has become stock-in-trade for instructional design models ranging from the whole-language approach to learning reading and writing, to various methods for training individuals within a corporate culture.

Social constructivism is related to the concept of stativity, which is discussed separately.

6.3. Piaget’s Theory of Cognitive Development and Learning

Piaget's (1936) theory of cognitive development is about how a child constructs a mental model of the world. Piaget was employed at the Benet Institute in the 1920s, where his job was to develop French versions of questions on English intelligence tests.

He became intrigued with the reasons children gave for their wrong answers to the questions that required logical thinking. He believed that these incorrect answers revealed important differences between the thinking of adults and children.

Piaget (1936) described his work as genetic epistemology (i.e. the origins of thinking). Genetics is the scientific study of where things come from (their origins). Epistemology is concerned with the basic categories of thinking, that is to say, the framework or structural properties of intelligence. What Piaget wanted to do was not to measure how well children could count, spell or solve problems as a way of grading their I.Q. What he was more interested in was the way in which fundamental concepts like the very idea of number, time, quantity, causality, justice and so on emerged.

Piaget (1936) was the first psychologist to make a systematic study of cognitive development. His contributions include a theory of child cognitive development, detailed observational studies of cognition in children, and a series of simple but ingenious tests to reveal different cognitive abilities. Before Piaget’s work, the common assumption in psychology was that children are merely less competent thinkers than adults. Piaget showed that young children think in strikingly different ways compared to adults.
According to Piaget, children are born with a very basic mental structure (genetically inherited and evolved) on which all subsequent learning and knowledge is based.

**Sensori-motor stage (birth to 2 years old)**
The infant builds an understanding of himself or herself and reality (and how things work) through interactions with the environment. It is able to differentiate between itself and other objects. Learning takes place via assimilation (the organization of information and absorbing it into existing schema) and accommodation (when an object cannot be assimilated and the schemata have to be modified to include the object).

**Preoperational stage (ages 2 to 4)**
The child is not yet able to conceptualize abstractly and needs concrete physical situations. Objects are classified in simple ways, especially by important features.

**Concrete operations (ages 7 to 11)**
As physical experience accumulates, accommodation is increased. The child begins to think abstractly and conceptualize, creating logical structures that explain his or her physical experiences.

**Formal operations (beginning at ages 11 to 15)**
Cognition reaches its final form. By this stage, the person no longer requires concrete objects to make rational judgments. He or she is capable of deductive and hypothetical reasoning. His or her ability for abstract thinking is very similar to an adult.

**6.4. Information Processing Theory**
The basic idea of Information processing theory is that the human mind is like a computer or information processor — rather than behaviorist notions that people merely responding to stimuli.

These theories equate thought mechanisms to that of a computer, in that it receives input, processes, and delivers output. Information gathered from the senses (input), is stored and processed by the brain, and finally brings about a behavioral response (output).

Information processing theory has been developed and broadened over the years. Most notable in the inception of information processing models is Atkinson and Tiffin’s ‘stage theory,’ presenting a sequential method, as discussed above, of input-processing-output[2]. Though influential, the linearity of this theory reduced the complexity of the human brain, and thus various theories were developed in order to further assess the inherent processes.

Following this line of thought, Crack and Lockhart issued the ‘level of processing’ model[3]. They emphasize that information is expanded upon (processed) in various ways (perception, attention, labeling, and meaning) which affect the ability to access the information later on. In other words, the degree to which the information was elaborated upon will affect how well the information was learned.
Brantford broadened this idea by adding that information will be more easily retrieved if the way it is accessed is similar to the way in which it was stored[4]. The next major development in information processing theory is Rumelhart and McClelland’s connectionist model, which is supported by current neuroscience research[5]. It states that information is stored simultaneously in different areas of the brain, and connected as a network. The amount of connections a single piece of information has will affect the ease of retrieval.

The general model of information processing theory includes three components:

**Sensory Memory**

In sensory memory, information is gathered via the senses through a process called transduction. Through receptor cell activity, it is altered into a form of information that the brain could process. These memories, usually unconscious, last for a very short amount of time, ranging up to three seconds. Our senses are constantly bombarded with large amounts of information. Our sensory memory acts as a filter, by focusing on what is important, and forgetting what is unnecessary. Sensory information catches our attention, and thus progresses into working memory, only if it is seen as relevant, or is familiar.

**Working Memory/short Term Memory**

Baddeley (2001) issued a model of working memory as consisting of three components. The executive controls system oversees all working memory activity, including selection of information, method of processing, meaning, and finally deciding whether to transfer it to long term memory or forget it. Two counterparts of this system are the auditory loop, where auditory information is processed, and the visual-spatial check pad, where visual information is processed. Sensory memories transferred into working memory will last for 15-20 seconds, with a capacity for 5-9 pieces or chunks of information. Information is maintained in working memory through maintenance or elaborative rehearsal. Maintenance refers to repetition, while elaboration refers to the organization of information (such as chunking or chronology).

The processing that occurs in working memory is affected by a number of factors. Firstly, individuals have varying levels of cognitive load, or the amount of mental effort they can engage in at a given moment, due to individual characteristics and intellectual capacities. Secondly, information that has been repeated many times becomes automatic and thus does not require much cognitive resources (e.g. riding a bike). Lastly, according to the task at hand, individuals use selective processing to focus attention on information that is highly relevant and necessary.

**Long Term Memory**

Long term memory includes various types of information: declarative (semantic and episodic), procedural (how to do something), and imagery (mental images).

As opposed to the previous memory constructs, long term memory has unlimited space. The crucial factor of long term memory is how well organized the information is. This is
affected by proper encoding (elaboration processes in transferring to long term memory) and retrieval processes (scanning memory for the information and transferring into working memory so that it could be used). As emphasized in Branford’s work, the degree of similarity between the way information was encoded and the way it is being accessed will shape the quality of retrieval processes. In general, we remember a lot less information than is actually stored there.

6.5. Bandera - Social Learning Theory
People learn through observing others’ behavior, attitudes, and outcomes of those behaviors [1]. “Most human behavior is learned observationally through modeling: from observing others, one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action.” (Bandera). Social learning theory explains human behavior in terms of continuous reciprocal interaction between cognitive, behavioral, and environmental influences.

Necessary Conditions for Effective Modeling
Attention — various factors increase or decrease the amount of attention paid includes distinctiveness, affective valence, prevalence, complexity, functional value. One’s characteristics (e.g. sensory capacities, arousal level, and perceptual set, past reinforcement) affect attention. Retention — remembering what you paid attention to includes symbolic coding, mental images, cognitive organization, symbolic rehearsal, motor rehearsal.

Reproduction — reproducing the image, including physical capabilities, and self-observation of reproduction. Motivation — having a good reason to imitate. Includes motives such as past (i.e. traditional behaviorism), promised (imagined incentives) and vicarious (seeing and recalling the reinforced model)

Reciprocal Determinism
Bandera believed in “reciprocal determinism”, that is, the world and a person’s behavior cause each other, while behaviorism essentially states that one’s environment causes one’s behavior[2]. Bandera, who was studying adolescent aggression, found this too simplistic, and so in addition he suggested that behavior causes environment as well[3]. Later, Bandera soon considered personality as an interaction between three components: the environment, behavior, and one’s psychological processes (one’s ability to entertain images in minds and language).

Social learning theory has sometimes been called a bridge between behaviorist and cognitive learning theories because it encompasses attention, memory, and motivation. The theory is related to Vygotsky’s Social Development Theory and Lava’s Situated Learning, which also emphasize the importance of social learning.

Observational Learning
Children observe the people around them behaving in various ways. This is illustrated during the famous Bubo doll experiment (Bandera, 1961).
Individuals that are observed are called models. In society, children are surrounded by
many influential models, such as parents within the family, characters on children’s TV,
friends within their peer group and teachers at school. These models provide examples of
behavior to observe and imitate, e.g. masculine and feminine, pro and anti-social etc.

Children pay attention to some of these people (models) and encode their behavior. At a
later time they may imitate (i.e. copy) the behavior they have observed. They may do
this regardless of whether the behavior is ‘gender appropriate’ or not, but there are a
number of processes that make it more likely that a child will reproduce the behavior that
its society deems appropriate for its sex.

First, the child is more likely to attend to and imitate those people it perceives as similar
to itself. Consequently, it is more likely to imitate behavior modeled by people of the
same sex.

Second, the people around the child will respond to the behavior it imitates with either
reinforcement or punishment. If a child imitates a model’s behavior and the
consequences are rewarding, the child is likely to continue performing the behavior. If
parent sees a little girl consoling her teddy bear and says “what a kind girl you are”, this
is rewarding for the child and makes it more likely that she will repeat the behavior. Her
behavior has been reinforced (i.e. strengthened).

Reinforcement can be external or internal and can be positive or negative. If a child
wants approval from parents or peers, this approval is an external reinforcement, but
feeling happy about being approved of is an internal reinforcement. A child will behave
in a way which it believes will earn approval because it desires approval. Positive (or
negative) reinforcement will have little impact if the reinforcement offered externally
does not match with an individual's needs. Reinforcement can be positive or negative,
but the important factor is that it will usually lead to a change in a person's behavior.

Third, the child will also take into account of what happens to other people when
deciding whether or not to copy someone’s actions. A person learns by observing the
consequences of another person’s (i.e. models) behavior e.g. a younger sister observing
an older sister being rewarded for a particular behaviour is more likely to repeat that
behaviour herself. This is known as vicarious reinforcement.

This relates to attachment to specific models that possess qualities seen as rewarding.
Children will have a number of models with whom they identify. These may be people in
their immediate world, such as parents or older siblings, or could be fantasy characters or
people in the media. The motivation to identify with a particular model is that they have a
quality which the individual would like to possess.
Identification occurs with another person (the model) and involves taking on (or adopting) observed behaviors, values, beliefs and attitudes of the person with whom you are identifying. The term identification as used by Social Learning Theory is similar to the Freudian term related to the Oedipus complex. For example, they both involve internalizing or adopting another person’s behavior. However, during the Oedipus complex the child can only identify with the same sex parent, whereas with Social Learning Theory the person (child or adult) can potentially identify with any other person.

Identification is different to imitation as it may involve a number of behaviors being adopted, whereas imitation usually involves copying a single behavior.
Unit 7

SOCIO-ECONOMIC FOUNDATIONS
OF SCIENCE EDUCATION-I

Written by: Dr. Hafiz Muhammad Ather Khan
Reviewed by: Arshad Mahmood
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INTRODUCTION

The impact of parents' socioeconomic status on their children's educational outcomes in Nigeria. Primary data was used in the study. Instrument used in data collection was questionnaire. One way analysis of variance (ANOVA) was the technique employed to analyze the data. An important finding is that there is a significant impact of parents' socioeconomic status on the educational outcome of children.

OBJECTIVES

After reading this unit you will be able to:
1. understand the relationship of science and society.
2. know about the culture of the society.
3. Understanding about social development.
7.1. Relationship between Science and Society
The impact of science and technology on society is evident. But society also influences science. There are social influences on the direction and emphasis of scientific and technological development, through pressure groups on specific issues, and through generally accepted social views, values and priorities.

Societies have changed over time, and consequently, so has science. For example, during the first half of the 20th century, when the world was enmeshed in war, governments made funds available for scientists to pursue research with wartime applications — and so science progressed in that direction, unlocking the mysteries of nuclear energy. At other times, market forces have led to scientific advances. For example, modern corporations looking for income through medical treatment, drug production, and agriculture, have increasingly devoted resources to biotechnology research, yielding breakthroughs in genomic sequencing and genetic engineering. And on the flipside, modern foundations funded by the financial success of individuals may invest their money in ventures that they deem to be socially responsible, encouraging research on topics like renewable energy technologies. Science is not static; it changes over time, reflecting shifts in the larger societies in which it is embedded.

7.2. Cultural Study of Science and Science Education
Examines science education as a cultural, cross-age, cross-class, and cross-disciplinary phenomenon. It establishes bridges between science education and social studies of science, public understanding of science, science and human values, and science and literacy. The journal provides an interactive platform for researchers working in the multidisciplinary fields of cultural studies and science education.

Cultural Studies of Science Education examines science education as a cultural, cross-age, cross-class, and cross-disciplinary phenomenon. It provides an interactive platform for researchers working in the multidisciplinary fields of cultural studies and science education. Moreover, the journal establishes bridges between science education and social studies of science, public understanding of science, science and human values, and science and literacy. By taking a cultural approach and paying close attention to theories from cultural studies, this new journal reflects the current diversity in science education. In addition, it reflects the variety of settings in which science education takes place, including schools, museums, zoos, laboratories, parks, aquariums, and community development, maintenance and restoration programs. In addition to original research articles, the journal publishes essays, OP-ED, comments, criticisms, and letters on emerging issue.

7.3. Science for Social Reconstruction
In the eighth Steinmetz Memorial Lecture delivered before the Schenectady Section of the American Institute of Electrical Engineers on January 10, Dr. C. E. Kenneth Mees, under the title “Scientific Thought and Social Reconstruction”, endeavoured to assess the contribution which men of science can make to the solution of our social and economic problems. While the lag between a scientific discovery and its application tends to
decrease and consequently the rate of change produced by scientific knowledge to increase, he does not think that the rate of change will continue to increase. It is highly probable that our social system is in an unstable phase, but after a period of rapid change in which the state of strain is relieved, it should settle into a new and stable phase. While admitting that the man of science must be actively concerned with the vast social and political experiments of our time, Dr. Mees does not consider it would be wise for him to take up the burdens of the politician. He believes that the chief contribution of science to social recon-struction is the method and spirit in which the scientific worker approaches his own work of creating ordered knowledge which is then available for all.

7.4. Science and Social Development

Social science is a major category of academic disciplines, concerned with society and the relationships among individuals within a society. It in turn has many branches, each of which is considered a "social science". The main social sciences include economics, political science, human geography, demography, and sociology. In a wider sense, social science also includes some fields in the humanities\[1\] such as anthropology, archaeology, jurisprudence, history, and linguistics. The term is also sometimes used to refer specifically to the field of sociology, the original 'science of society', established in the 19th century. A more detailed list of sub-disciplines within the social sciences can be found at Outline of social science.

Positivist social scientists use methods resembling those of the natural sciences as tools for understanding society, and so define science in its stricter modern sense. Interpretive social scientists, by contrast, may use social critique or symbolic interpretation rather than constructing empirically falsifiable theories, and thus treat science in its broader sense. In modern academic practice, researchers are often eclectic, using multiple methodologies (for instance, by combining the quantitative and qualitative researches). The term social research has also acquired a degree of autonomy as practitioners from various disciplines share in its aims and methods.

Education encompasses teaching and learning specific skills, and also something less tangible but more profound: the imparting of knowledge, positive judgment and well-developed wisdom. Education has as one of its fundamental aspects the imparting of culture from generation to generation (see socialization). To educate means 'to draw out', from the Latin educated, or to facilitate the realization of an individual's potential and talents. It is an application of pedagogy, a body of theoretical and applied research relating to teaching and learning and draws on many disciplines such as psychology, philosophy, computer science, linguistics, neuroscience, sociology and anthropology.\[15\]

The education of an individual human begins at birth and continues throughout life. (Some believe that education begins even before birth, as evidenced by some parents' playing music or reading to the baby in the womb in the hope it will influence the child's development.) For some, the struggles and triumphs of daily life provide far more instruction than does formal schooling (thus Mark Twain's admonition to "never let
school interfere with your education”). Family members may have a profound educational effect — often more profound than they realize — though family teaching may function very informally.

7.5. Science for Leadership
The Master of Science in Leadership (MSL) is a master's degree in leadership studies that is offered by a college of business. It is an alternative to, not a substitute for, the traditional Master of Business Administration (MBA) degree. The MSL degree requirements may include some business/management courses that are required in an MBA program. However, this degree program concentrates heavily on leader-follower interactions, cross-cultural communications, coaching, influencing, team development, leading organizational changes, strategic thinking, project leadership, and behavioral motivation theories. It does not concentrate on financial or quantitative analysis, marketing, or accounting which are common in MBA programs. The degree program is appealing to businesspeople in well-established careers already. The MSL degree is similar to the Master of Science in Organizational Leadership (MSOL) degree or the Master of Leadership Sciences degree offered by the National School of Leadership in India.
SOCIO-ECONOMIC FOUNDATIONS
OF SCIENCE EDUCATION-II

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INTRODUCTION

Science and technology has transformed the life and helped the man to improve the quality of life by: increasing life expectancy, controlling diseases and hence mortality rate, decreasing large scale famine, which can decimate population by making availability of new sources of energy.

However, all this could not be achieved without economic development for which, it is believed, development in science and technology are indispensible. This unit reviews the links between science and economic development.

The first section of this unit analyses the link between science and progress. The unit reviews as to how development in science results in the development and progress. The unit reviews as to how development in science results in the development of technology. The second section discusses the link between progress of science and economic development. The last section of this unit reviews the factors responsible for globalization of the concept of science education for economic development.

OBJECTIVES

After reading this unit you will be able to:
1. know about progress of science.
2. understand the concept of science and economic development.
3. social implementations of science and science development.
4. know the importance of globalization and science education for development.
8.1. Science and Progress
Several philosophers of science have supported arguments that the progress of science is discontinuous. In that case, progress isn't a continuous accumulation, but rather a revolutionary process where brand new ideas are adopted and old ideas become abandoned. Thomas Kuhn was a major proponent of this model of scientific progress, as explained in his book *The Structure of Scientific Revolutions*.

This is especially supported by studying the incommensurability of theories. For example, consider Newtonian mechanics and relativistic mechanics. From a strict vantage point, in Newtonian mechanics mass and energy are always conserved, where in relativistic mechanics energy and mass are always interchangeable. (Note the difference between the strict vantage point, and the layperson's vantage point that Newton's theory is applicable at low energies and low velocities relative to the velocity of light.) Because the theories are completely incompatible, scientists using one paradigm will not be able to discuss meaningfully with scientists from the other paradigm.

A discontinuous model of scientific progress may disagree with a realist's construction in the philosophy of science. This is because the intrinsic nature of the objects referred to may change wildly.

Science is often distinguished from other domains of human culture by its progressive nature: in contrast to art, religion, philosophy, morality, and politics, there exist clear standards or normative criteria for identifying improvements and advances in science. For example, the historian of science George Sarton argued that “the acquisition and systematization of positive knowledge are the only human activities which are truly cumulative and progressive,” and “progress has no definite and unquestionable meaning in other fields than the field of science” (Sarton 1936). However, the traditional cumulative view of scientific knowledge was effectively challenged by many philosophers of science in the 1960s and the 1970s, and thereby the notion of progress was also questioned in the field of science. Debates on the normative concept of progress are at the same time concerned with axiological questions about the aims and goals of science. The task of philosophical analysis is to consider alternative answers to the question: What is meant by progress in science? This conceptual question can then be complemented by the methodological question: How can we recognize progressive developments in science? Relative to a definition of progress and an account of its best indicators, one may then study the factual question: To what extent, and in which respects, is science progressive?

8.2. A Critical Appraisal of Science for Economic Development
Expert advice and lay-notions regard science as an essential social institution: science is a necessary element of modern education; it is a building block for personal and social development, and its products advance human society and offer prosperity. Science is also
considered as an integral part of modernity, of advanced nations and of enlightened and
civilized societies. We judge nation-states by their scientific performance or by their
utilization of technology. We compare societies by their level of scientific literacy or by the
number of great inventors from their ranks. We observe that the more advanced societies
are those with most advanced science institutions, and, thus, we conclude that science and
national progress are causally linked. Scientific progress rests on scientific knowledge and
scientific skills; hence, science education is essential to future scientific advances and to, in
turn, economic prosperity. Consequently, in our everyday life we assign science education
the social role of bringing progress to society, especially to the most needy of societies.
This social role of science education is taken-for-granted: we assume it as such, we act
upon it, and rarely do we question our opinion of science education. I suggest that we pose
to reassess our standing towards science education and towards the social role that we assign to it. In this chapter I offer some evaluations of our everyday notion of science
education and of the translation of this everyday belief into social policy.

8.3. Social Constraints in Implementation of Science Development
The natural environment functioning through an entangled network of interactions must
be dealt with an integrated perspective (Bower and Turner 1998). Because integrated
environmental concepts are rather recent, scientific tools available for the holistic
understanding of environmental processes are still scarce. Progress towards integration
requires new scientific approaches to ensure sustainability of resources and to attain the
necessary integrated management (Healey and Hennessey 1994).

Coastal areas include sensitive environments (deltas, estuaries, etc.), which are subject to
changes occurring on land and in the sea. The ideal management of these regions should
include the whole area extending from the watersheds of the hydrographical basins to the
external limits of the Exclusive Economic Zone (GESAMP 1996). However, there are
rare successful examples of managing such large areas since various factors interfere in
the process, as for instance: poor intergovernmental, intermedia, intersectorial and
interdisciplinary integration (Knight and Archer 1993); poor governance initiatives, lack
of reliable data (Olsen 2001).

In addition, uncontrollable anthropogenic factors which are remarkable in developing
areas, as for instance, population expansion and increasing trends of coastal occupation
(Cohen et al. 1997, Along 1998) interacting with the complexity of the natural
environment may undermine predictions (planning) as well as the outputs of management
and conservation actions. Sustainability is especially sensitive to changes in demand upon
natural resources (Pearce and Turner 1990) that, in turn, are strongly driven by these
factors that are difficult to manage. Policymakers and managers in developing countries
are continuously confronted with such uncertainties while proceeding often unaware of
the benefits derived from an effective interaction with the science sector (Schwarzer et al.
2001) at an early stage of planning.
The present paper reviews and discuss two key factors which impair the implementation of effective coastal management programmes in developing countries: the lack of monitoring strategies capable of increasing access to reliable knowledge, and barriers to the dissemination of scientific information needed to achieve outputs from national and international actions aiming at coastal conservation.

**Existing monitoring regimes / actual needs in developing world coastal areas**

Lee (1993) proposes that integrated coastal management rely upon two pillars, the governance process and the reliable knowledge about the ecosystem functioning. In developing countries, information on the status and properties of the coastal environments are scarce. Actions towards mitigation and conservation cannot depend on the initiation of long-term data acquisition through scientific surveys which should have been conducted in the early stages of coastal occupation. However, properly designed monitoring activities carried out as a component of adaptive management may provide a substantial fraction of the required knowledge (Lee 1993).

Monitoring is a continuous process in time providing basis for evaluation and correction of management actions (Davenport 2003). The high costs associated to traditional methods of monitoring are constraining the use of continuous environmental observations in developing countries. Most frequently adopted procedures - often unsystematically - add very little information on the ecological integrity of the system under observation.

The recently introduced watershed management approach implies monitoring at medium scales (Boesch 1996) - for instance, a whole hydrographical basin as opposed to a single river or bay - a task that requires the development of observation and control systems effective at these scales. The geographic magnitude of ongoing internationally funded activities in developing countries, as those in the São Francisco River Basin in Brazil (640,000 km² of area) (United Nations Environmental Programme (UNEP)/Global Environmental Facility (GEF) Project: Integrated Management of Land Based Activities in São Francisco Basin) and in the Pantanal Upper Paraguay Transboundary River Basin (496,000 km² of area) (UNEP/GEF Project: Integrated watershed management programme for the Pantanal and Upper Paraguay River Basin), imposes the implementation of complex monitoring arrays. In the case of the São Francisco River the construction of five dams endangers coastal stability and natural habitats in view of the steady reduction in sediment supply to the estuarine region, the decrease in water flow and changes in the flood regime (Medeiros and Knoppers, unpublished data). In spite of the existing scientific information demonstrating severe water depletion in this basin due to diverse uses, a programme has been considered to transpose water from the São Francisco River to a large and poor arid region in the Northeast of the country.

The feasibility of this programme strongly depends upon including the Tocantins River Basin (Araguaia-Tocantins Basin - 800,000 km²) in the management plan of the São Francisco River.
Francisco, in addition to the reallocation of water resources and users coupled to a new policy for water distribution. In both basins, since anthropogenic activities also induce water contamination (mercury, pesticides, nutrients, trace metals) and decrease in water quality, an array of technical, social and legal interventions must be built in targeting the reduction of inputs and the introduction of monitoring. Evidently effective monitoring requires implementation of a robust observation network and adoption by all enrolled institution of common scientific approaches and standardized quality assurance practices.

Conventional water quality standards originally established for temperate environments 30 to 40 years ago have been later adopted in many developing countries as guidelines to evaluate environmental conditions in coastal areas and to design monitoring programmers. Besides providing poor performance in coupling, for example, measured pollutant concentrations to a specific response in the ecosystem these standards are inadequate to identifying trends derived from continuous exposition to low or moderate levels of chronic stresses which may adversely affect biodiversity. There is an urge for revision of monitoring strategies as to include scientific tools (USEPA 2002) that: (1) are capable of providing information on adequate (or desirable) levels of environmental conditions and/or on changes in sustainability (or in the carrying capacity); (2) respond to early signs of alterations; (3) are flexible and robust as to be applicable under different settings.

Often environmental scientists are unable to provide managers and policy maker with fair estimates of "how much is too much" in terms of contamination (Cicin-Sain and Knecht 1998). This limitation has contributed to delaying the establishment of environmental thresholds and criteria based on actual knowledge.

For decades the sea was considered as the ultimate sink for sewage, litter and toxic residues. Although this view has progressively changed over the last 15-20 years often in developing regions financial limitations allied to poorly prepared personnel enrolled in managerial activities have led to continuing the practice of releasing wastes directly in estuaries and coastal areas. There is little awareness of inadvertent potential risks imposed by "traditional" sources of contamination, as for instance the domestic sewage.

The development of powerful analytical and assessment techniques in the last 20 years led to a significant advance in understanding of the complex composition of a number of contamination sources, and the dependence of cause-effect relationships on specificity of the source, of the contaminant, and of the recipient water body. This knowledge has not been fully integrated either in the management routine or in designing monitoring activities.

In many areas of the developing world, raw domestic sewage is directly delivered into coastal waters by means of submarine outfalls. Frequently drainage waters are also collected by such installations. As for the major sewage components, coastal dynamics may be sufficient to reduce nutrient concentration in recipient waters to an acceptable
level but nitrogen species delivered by sewage (ammonia and urea) differs from the main nitrogen species (nitrate) in the ocean. This changed speciation superimposed to alterations in the nitrogen/phosphorus ratio leads to changes in ecological structure and to surges of unwanted opportunistic species (Smayda and Shimizu 1993). Although the bulk nutrient concentration may turn out within acceptable levels in dynamic coastal areas, the changing nutrient speciation and its ecological consequences may lead to ranking the resulting environmental risk as "too much".

For the manager and decision makers in developing countries the main concern is to give a final destination to waters enriched in nutrients, organic matter and pathogens with the lowest possible investment. In general, little, if any, attention is given to the complex composition of urban sewage and the associated risk of releasing persistent toxic substances or resistant microorganisms in the sea (Goldberg 1993).

In the large urban centers, drainage waters carrying polycyclic aromatic hydrocarbons, trace metals and pesticide residues are discharged through submarine outfalls or other discharge systems in association with the domestic sewage that also contain harmful substances (antibiotics, hormones, pesticide residues, chemicals used in household, cosmetics, etc.; some of them cannot be effectively removed by conventional treatments when those are at all available). Some of these substances are suspect to act as endocrine disrupters (Lye et al. 1999, Jobbing et al. 1998) and little is known about the long-term effects they may have upon the marine biota, even at low concentrations.

In the coastal area of Rio de Janeiro, Brazil, the two decades of a submarine outfall operation resulted in the buildup of trace metal contamination in the surrounding waters (Wagener et al. 1992) and in the biota (Franconia et al. 2004) that eventually may return to man through the food web. Sediments contain polycyclic aromatic hydrocarbons (PAHs) at levels (256 ng.g⁻¹; unpublished data) comparable to those reported for the heavily industrialized area of the Rhone (Lipitor and Saliot 1991).

It is true that frequently poorer urban areas are not even served by sewage collection systems. In this case rivers, channels and drainage water contaminated with pathogens may flow with peak intensities during the tropical rain season directly into beaches and recreational waters. This is a severe threat to public health in urban centers, as in Rio de Janeiro, where beaches are a preferred recreational option for hundreds of thousands. Water quality control based on E. coli counting, when present, may have minor impact in prevention of enteric diseases because of the usual long time lag between sampling and releasing balneability information to the public.

Last but not least, it is well known today that a number of virus and bacteria may survive longer in seawater than expected earlier when recreational water criteria were solely based on faecal coliforms. Health risk related to bathing in contaminated seawater or
eating raw seafood may be, therefore, greater than presumed (Murray and Lopez 1996, CGER 1999). In this concern more adequate criteria must be tested in developing regions and adopted to protect human health (WHO 2003).

A serious barrier to management of coastal areas in developing countries arises from lack of funding mechanisms to support the acquisition of time series data and continuous monitoring. Data collection often fragmented fails in the necessary robustness to support trend recognition and forecasting.

Also in the industrialized countries, the relatively late implementation of continuous observation activities at the national and regional levels resulted in the scarcity of long term data characterizing cross-interactions among contaminants/anthropogenic induced stresses, natural variations, and the ecosystem (Rabelais et al. 2000).

A successful example of continuous observations is the National Status and Trends Program established in 1984 to provide long term dataset to track changes in the US coastal environmental quality. This programmer includes two on going projects, The Mussel Watch Project and the Bioeffects Assessment Project, and the Benthic Surveillance Project terminated in 1993. The two on going projects aim at monitoring organic and inorganic contaminants in sediment and bivalve samples from coastal waters of US as a basis to identifying risk areas. The importance of long term observation is highlighted by the conclusion drawn that it was possible to determine existing environmental trends only for sites at which six or more years of data are available (Lauenstein and Canutillo 2002).

In the developing countries long term observations are virtually absent although they are vital to understanding the chronic effects of pollution and other disturbances upon the aquatic ecosystems.

For instance, the long term effects of eutrophication are little known although nutrient enrichment is a major problem of global importance because of the effects on the metabolism of aquatic systems (Kemp et al. 1997). The immediate responses to increased nutrient load, as the decrease in dissolved oxygen, tendency to hypoxia and appearance of alga blooms are well documented (Officer et al. 1984, Rebello et al. 1988, Turner and Rabalais 1994, Balls et al. 1995, Hogarth et al. 2000). More difficult to access are the long-term effects upon species at several tropic levels and the losses in biodiversity for which the economic consequences must still be quantified. A strong example of such alterations occurred in Guanabara Bay, an urban estuary in Rio de Janeiro, Brazil, where eutrophication has often led to the surge of unwanted toxic algae species followed by fish mortality and to a major contribution of cyan bacteria to the algae pool (Valentin et al. 1999). Nowadays, gastropods (Stramonita hematomas) and molluscs (Pena perna) cannot
be found in the inner and most contaminated regions of the bay where they were abundant in the past.

Recent investigations in sediment cores showed an additional but less obvious change in Guanabara Bay, a 10-fold increase in the sedimentary carbon and nutrient pool that occurred over the last 50 years (Carriers et al. 2002) as resulting from the increment in carbon fixation allied to high sedimentation rates (1-2 cm.year⁻¹). Time trends of coprostanol, a faecal molecular marker, and other sterols recorded in dated sediment cores confirmed the link between these increments and the increasing sewage contamination in Guanabara Bay (Carriers et al. 2004).

Geochronological investigations, as these cited above, have been useful in elucidating trends and past environmental conditions (Valetta-Silver 1993). Recent advances in the field of organic geochemistry may credit new dimension to investigations aimed at understanding time changes in species dominance and alterations in the productivity/respiration ratio resulting from eutrophication. Chemical molecules reasonably well preserved in sediments that can be traced back to original substances produced by specific organisms - bacteria, cyan bacteria, diatoms, din flagellates, etc - (Bianchi and Cancel 2001, Zimmerman and Cancel 2002, Carrier et al. 2002) appear as powerful tools in monitoring these changes. Investigations applying such tools in dated sediment cores are capable of reproducing trends derived from increased nutrient loads and demographic growth. In very altered coastal ecosystems, for instance, this information allied to statistical data on source intensity and demographic/agriculture growth are essential for the understanding of threshold levels that triggered substantial or even irreversible changes. Managers should make use of such information to support objective decisions on the appropriate/desirable carrying capacity that must and can be recovered, and estimate the necessary investments.

A substantive problem in tropical coastal systems is the increase in sedimentation rates due to deforestation and improper soil management/occupation (Rebelled et al. 1986, Godoy et al. 1998). The increased sedimentation poses at least three major problems: the loss of habitat, the decrease in recreational and economically useful area and the increment of toxic substances stored in sediments (Charles and Hits 1987, Cleverly et al. 1996). Geochronology also aids in estimating fluxes from contaminated sediments that may be an important supply of nutrients, as forecasted for Guanabara Bay (Rebello et al. 1988), and toxic substances long after the land sources have been reduced. Decisions on the use of expensive but safe procedures of removing contaminated sediments and rehabilitating silted areas should be based upon this source strength knowledge as to evaluate cost/benefit. Environmental liabilities maybe estimated from such observations, and reductions in sediment loads in response to reforestation program or to adequate soil management can easily be verified.
Promising Monitoring Technologies for Coastal Areas

The conventional environmental indicators (BOD, dissolved oxygen, bulk nutrient concentration, particulate matter, faecal coliforms) most frequently applied to monitor areas subjected to domestic sewage inputs do not address the above issues. They also fail in expressing vital systemic changes in the environment and the consequent impact on the biota or the actual risk to human health (Paul et al. 1997). This is a common limitation of most environmental indicators under current use, which are solely based upon monitoring concentration changes in environmental compartments.

The biomarker concept that advanced rapidly over the last decade may become a useful tool in the observation of systemic changes occurring in marine ecosystems and, therefore, in coastal management. The concept is based on biological or/and biochemical expressions appearing as a response from organisms to exposure to contaminants and other environmental stresses (Deplete and Fossil 1994, Deplete et al. 1995, Fossil et al. 2000). The great majority of the already tested biomarkers respond to more than one group of stressing forces, and the more specific the tests the higher are the costs of use and technical expertise required. There are, however, robust biomarkers that are suitable indicators of stressing environmental conditions although less intensive on costs/technical expertise. The micronucleus assay (Brunette et al. 1998) that responds well to exposure to carcinogenic substances and the non-specific lysosome assay (Cheung et al. 1998) are some examples of tests that may suit well conditions in developing countries.

Both these tests were successfully applied in monitoring impacts derived from oil spills in Guanabara Bay, Rio de Janeiro. Mussels *Perna perna* have proved to be excellent biomonitors for oil contamination in the bay since their PAHs bioaccumulation follows closely concentration changes in the water column with little departure from the original oil composition (Francioni et al. 2005). The analysis of polyaromatic hydrocarbons in mussel tissue is costly especially if alkylated polycyclic aromatic hydrocarbons are included as required in chemical forensics. Preliminary results obtained by applying the neutral red (lysosome assay) in mussels *Perna perna* from contaminated and uncontaminated areas demonstrated the good performance of this inexpensive approach to monitor acute oil releases. Organisms in pristine areas showed long retention times for neutral red in the liposome compartments but because of the chronic contamination state in Guanabara Bay low retention times are continually observed in the mussels from the bay. The usual statistical distribution of the retention times for each observed population shows a wide range of values as expected in biological systems exposed to steady state conditions. Nevertheless, after an oil spill in January 2000 data distribution for the sampled population in the bay was strikingly different although average retention times were in the range observed prior to the spill. The oil spill caused a three-fold increase in PAH concentration (from an average of 500 ng.g\(^{-1}\) to 1700 ng.g\(^{-1}\)) in the mussels and the individually different responses to the neutral red assay were cancelled out (from an average variance of 42% to 0). The phenomenon that there was no distribution of the
results may result from a threshold reaction indicative of particularly altered environmental conditions (Franconia et al. 2005). These useful observations provided a basis for the safe application of the technically simple and inexpensive neutral red test to monitor acute events in this chronically altered bay.

The managerial value of biomarkers also relies on the possibility to detect biological responses at early stages of environmental changes. Moreover, different from usual ecotoxicology assays, they are applied in population samples exposed to the in situ conditions. The concurrent evaluation of concentration levels of suspected contaminants contributes to the gradual establishment of more adequate environmental criteria. Besides the information on the status of individual species, when applied on a continuous basis to organisms selected as to represent different tropic levels, biomarkers are likely to be useful in recognizing trends of systemic changes. The tests are also useful in controlling illegal releases of contaminants in areas subject to conservation activities and as means to obtain early warnings on changes in pristine regions.

Immunoassays based on enzymatic or antigenic reactions are promising tools to be applied in monitoring (Muhlenberg et al. 1995, Waters et al. 1997, Barceló et al. 1998). A number of commercially available kits has been validated for direct application. The immunoassay test is less expensive than a traditional complete chemical analysis - as for instance for pesticides and polycyclic aromatic hydrocarbons (15 US dollars as compared to 180 US dollars for the complete chemical analysis); its application requires some training but is less labour intensive than most analytical procedures; it can provide quasi real time data; and reproduce a biochemical reaction to a toxicant. Because of possible cross-reactivity immunoassays are more suitable for application in routine monitoring, when base line data are already available, or in the inspection of large areas to identify hot spots. Franconia et al. (2003) used the test that responds to BTEX to localize hot spots of gasoline contamination in soils and compared the results with those from traditional chemical analysis obtaining a linear correlation coefficient (r²) of 0.998. Even substances that are difficult and expensive to monitor, as dioxins, are potential candidates to be currently detected by immunoassays in the near future. In developing regions where funds and lack of sufficient trained personnel are limiting the scope and frequency of monitoring activities, the use of immunoassays is an interesting option for environmental screening.

**Additional Barriers**

Coastal managers and environmental agencies in developing countries have to deal with institutional and economic limitations; however, a key constraint to the effective management is the difficult access to scientific information (Millard and Sayers 1999).

The capability to organise the existing information as to allow causal chain identification through a cross-linking of events (for example, the relation between level of sewage contamination in the beaches and the number of working hours lost due to enteric
diseases) is also deficient. There is an obvious need for improving the access to scientific information in a comprehensive format useful to managers (Schwarzer et al. 2001).

Tackling this problem requires first a revision of strategies so far dominant in the ways scientific information is disseminated. Emeis et al. (2001) considered that communication of scientific issues to managers is humped due to controversy and conflicting signals among other factors. In many developing countries communication turns out intrinsically difficult due to other factors in addition, as for instance, the use of international journals as the unique channel to convey scientific findings. Managers and decision makers in such countries usually have no easy access to these journals and neither are they trained to extract useful information from these publications directed to the scientific community. Information of so-called local interest do not reach acceptance in a number of international journals and may rest unreachable to the interested user if not even a national or regional scientific publication system is in place. Furthermore, it is truth that in the so-called century of communication many areas of the world have no straightforward access the abundant information in the Internet.

There is a great need to bring up scientific communication directed to non-scientists in the developing countries, including capacity building at the media level. The media contribution to the dissemination of local or regional scientific advances to the public in general is scare or of very poor quality. It fails in raising awareness and in contributing as it could to foster public and private investments in the science sector. Internationally funded projects are rarely addressing this issue although they often deal with capacity building initiatives.

A consensus does not yet exist on the best procedure to adopt in communicating scientific facts to managers, policy makers and other stakeholders, therefore different modalities should be adapted to the local/regional cultural, social and political scenario. Nevertheless, the resulting communication instrument should be flexible and independent as to allow free flow of ideas and information.

In developing countries the performance of regulatory environmental agencies is deeply subjected to the will of the actual political current in power. Effectiveness of communication may be affected by the fragility of these important institutions. Recent experiences gained in assessment projects carried out in the Todos os Santos Bay, Bahia (Wagener et al. 2003), and Guanabara Bay, Rio de Janeiro (Wagener et al. 2002), revealed that although the same set of communication instruments (meetings, reports seminars) have been used in both cases the supportive political atmosphere in Bahia was a key factor ensuring the strong commitment of the state environmental agency that, in turn, greatly facilitated a successful interaction with scientists.
Appropriate grounds for testing and stimulating different communication approaches are the Global Environmental Facility (GEF) funded projects because of the available organisational infrastructure and the potential to agglutinate different sectors at the local and regional scale.

These projects offer, in addition, the proper ground to test monitoring approaches that include participation of members of the local communities. Although in recent years indigenous knowledge emerged as a desirable component of internationally funded projects in developing countries little guidance has been given to create greatly needed job opportunities through the formal hiring of community members to perform simple but effective monitoring practices. There are, however, examples of community volunteers carrying out water quality monitoring as in the case cited above of the São Francisco River project. From top to down in the scale of complexity a number of opportunities not yet experienced in coastal management in developing countries is available to ensure feasibility, good performance and sustainability of monitoring activities.

Conclusions
The coastal environmental problems in developing countries are increasing dramatically as a result of the uncontrolled population growth and unsustainable development practices. Monitoring the environmental alterations, as a necessary basis for planning mitigation actions and source reduction, is a challenge under the present settings of deficient technical and economic capabilities in these countries. These shortcomings can be partly overcome by making use of fast screening methods, which are based, for instance, on biomarkers of stress and immunoassays, enrolling community members in the process and improving interaction among policy, managerial and scientific sectors. Still, practices, criteria and regulations adopted in developed countries must undergo a critical evaluation as for their suitability to current natural and economic conditions before acceptance in developing tropical areas. In this regard, introduction of local scientific knowledge in the formulation of regulatory instruments related to impact assessments and monitoring represents an important step forward in identifying site-specific needs and useful tools.

8.4. Science Education and Underdevelopment
After recognizing a need for more students and graduates in science, technology, engineering and mathematics, Sen. Conrad Appeal, R-Metairie, drafted Senate Resolution 120. The resolution asks Louisiana's top higher education board, the Board of Regents, to develop a strategy to attract and keep students in those degree fields to supply companies in New Orleans with a larger, more capable work force.

"It's clearly important that our best and brightest stay in Louisiana," Appeal said. "We have to be in a position to compete on a world basis. These are the jobs for the future." In April, Appeal drafted the resolution after spending time looking into the
issue at the university level. He expects the board to come out with a study and report in the next nine months. He hopes that the board will come up with strategies that can be turned into pieces of legislation that will induce more students to pursue degrees in the so-called STEM fields, science, technology, engineering and mathematics. "If we're going to fit into the 21st century we need more people graduating in these fields," Apple said. "The amount of income you can earn in these related fields is the best. Let's push for the future."

8.5. Globalization of Science Education for Development

Processes of globalization have played a major role in economic and cultural change worldwide. More recently, there is a growing literature on rethinking science education research and development from the perspective of globalization. This paper provides a critical overview of the state and future development of science education research from the perspective of globalization. Two facets are given major attention. First, the further development of science education as an international research domain is critically analyzed. It seems that there is a predominance of researchers stemming from countries in which English is the native language or at least a major working language. Second, the significance of rethinking the currently dominant variants of science instruction from the perspectives of economic and cultural globalization is given major attention. On the one hand, it is argued that processes concerning globalization of science education as a research domain need to take into account the richness of the different cultures of science education around the world. At the same time, it is essential to develop ways of science instruction that make students aware of the various advantages, challenges and problems of international economic and cultural globalization. Keywords: Globalization; science education research; science instruction.

Science education research has become increasingly concerned with the diversity of students in the classroom as demonstrated by the increase in articles on issues of equity in the last 10 years. However, much of this diversity literature does not address the complexity of the issues of indigenous learners in their postcolonial environments and calls for a “one size fits all” instructional approach (Lee, 2001). Now more than ever, indigenous knowledge needs to be promoted and supported. As globalization continues to increase, it allows for contact between once geographically isolated groups, and traditional knowledge systems are being assimilated and in some cases disappearing all together. For many indigenous peoples, this type of culture is one of colonizing, although due to increased globalization, the means of colonizing is changing. In a time of globalization in terms of technology and increased worldwide travel where populations migrate, indigenous knowledge is often dismissed as irrelevant and the Internet makes location an intangible concept. However, increasing local achievement in science and science education is advocated by a number of researchers in order to provide opportunities for people globally (McKinley, 2005). This issue of making local knowledge part of the global brings with it the challenges of politics, history, language,
economics and ethics. Throughout this paper, I will address these challenges and discuss ways to overcome these difficulties by focusing on place based science education that supports indigenous knowledge. As educators become more immersed in exploring traditional belief systems and finding a place for them in the Western world, the youth of many indigenous groups are becoming disinterested in their own native culture. Among the youth, a negative view of their culture has been championed by the lack of value the Western world has traditionally placed on these knowledge systems. However, in the last few decades, voices of educators and indigenous peoples themselves have led an awareness of the importance of IK. Encouragingly, some indigenous societies are keeping their cultural autonomy intact and demand for local curricula despite the modern domination of the Western world. An acknowledgement of this domination has been spreading, even in industrialized societies. Educators are beginning to recognize that Western-based formal knowledge remains just one knowledge system of many. Though traditional knowledge has long been, and often continues to be, assigned a lower status in both development and scientific circles than Western-based science and technology, the value of IK in science has been receiving increasing attention. Previously, the literature treated all minorities and indigenous peoples as requiring similar solutions to under achievement and this created exclusions for many people as individual voices and struggles were ignored.
Unit 9

SCIENCE EDUCATION IN GLOBAL PERSPECTIVE

Written by: Dr. Hafiz Muhammad Ather Khan
Reviewed by: Arshad Mahmood
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INTRODUCTION

A Global Perspective is ‘global’ both in content and authorship. Its 17 chapters by an assemblage of seasoned and knowledgeable science educators from many parts of the world seek to bring to the fore current developments in science education and their implications. The book thus covers a wide range of topics in science education from various national and international perspectives. These include the nature of science, science and religion, evolution, curriculum and pedagogy, context-based teaching and learning, science and national development, socially-responsible science education, equitable access for women and girls in science and technology education, and the benefits of science education research. It ends on an optimistic note by looking at science education in 50 years’ time with a recommendation, among others, for stakeholders to take the responsibility of preparing children towards a blossoming science education sector in an anticipated future world. This book is suitable for use by discerning researchers, teachers, undergraduate and postgraduate students in science education, and policy makers at all levels of education. Other educationalists and personnel in science and technology vocations will also find it interesting and useful as the reader-motivated approach has guided the presentation of ideas.

OBJECTIVES

After reading this unit you will be able to:

1. Understand the concept of science education in developed and developing countries.
2. know about importance of science education in Pakistan.
3. aware about future trends in science education.
9.1. Science Education in the Developed Countries

In the past two decades, a consensus has emerged that science should be a compulsory school subject. However, whilst there is agreement that an education in science is important for all school students, there has been little debate about its nature and structure. Rather, curricula have simply evolved from pre-existing forms. Predominantly these curricula have been determined by Scientists who perceive school science as a basic preparation for a science degree – in short a route into science. Such curricula focus on the foundational knowledge of the three sciences – biology, chemistry, and physics. However, our contention is that such an education does not meet the needs of the majority of students who require a broad overview of the major ideas that science offers, how it produces reliable knowledge and the limits to certainty. Second, both the content and pedagogy associated with such curricula are increasingly failing to engage young people with the further study of science. Indeed, there is a strong negative correlation between students’ interest in science and their achievement in science tests. Much of the current concern about science education, expressed in reports such as *Europe Needs More Scientists* [1], concentrates solely on the supply of future scientists and engineers and rarely examines the demand. There is, for instance, a failure to recognize that science is a global activity where the evidence would suggest that there is no overall shortage at the doctoral level [2] although there may be local shortages of particular types of scientists and engineers, for example, pharmacologists in the UK. There may also be shortages at the technician and intermediate levels of scientific and technological work but better data is needed before making major policy decisions on science education. In such a context, encouraging or persuading young people to pursue careers in science without the evidence of demand would be morally questionable. In addition, transforming young people’s attitudes to science is a long-term project. Even if it could be achieved readily, it would be at least a decade before any notable change in the supply would be noticed. Rather, the normative economic means of manipulating supply is through adjusting the financial remuneration offered to individuals. The problem with framing the discussion about school science in terms of the supply of the next generation of scientists is that it defines the primary goal of science education as a pipeline, albeit leaky. In so doing, it places a responsibility on school science education that no other curriculum subject shares. Our view is that a science education for all can only be justified if it offers something of universal value for all rather than the minority who will become future scientists. For these reasons, the goal of science education must be, first and foremost, to offer an education that develops students’ understanding both of the canon of scientific knowledge and of how science functions. In short that school science offers an education in science and not a form of pre-professional training.

Most school science curricula do attempt to serve two goals – that of preparing a minority of students to be the next generation of scientists – and that of educating the majority in and about science, most of whom will follow non-scientific careers. For the future scientist, their education best begins with the fundamentals of the discipline. In this approach, only students who reach a relatively high level of education in science develop a sense Yet it is this latter understanding – good examples of which can be found in the better quality of popular science writing [3] – that everyone requires. Asking the school science curriculum and teachers of science to achieve both of these goals simultaneously places school science in tension where neither goal is served successfully. In addition, the
standard school science education has consistently failed to develop anything other than a naive understanding of the nature of science, commonly called Traditional curricula in school science suffer from a number of difficulties. Knowledge is usually presented in fragmented concepts where the overarching coherence is not even glimpsed let alone grasped – an experience which has been described as akin to being on a train with blacked-out windows – you know you are going somewhere but only the train driver knows where. In addition, there is a growing gulf between the focus of school science – commonly the achievements of the 19th and early 20th Centuries – and the science that is reported in the media, such as astrophysics, neuroscience and molecular genetics.

Moreover, there still remains an enduring problem with the proportion of girls entering physical sciences and engineering in many but not all EU countries. Research has shown that there is a significant disparity between the aspects of science that interest girls and those that interest boys inviting the question as to what extent extant curricula serve the interests of girls?

9.2. Science Education in Developing Countries

The authors herein offer the science education community perspective on several issues that influence the teaching and learning of science in developing countries. Moreover, they identify emerging priorities for science education in developing world contexts. Concomitantly, this issue ought to raise the consciousness of individuals in “First World nations” to the issues, concerns, and contextual realities associated with teaching and learning science. Ideally, this Theme Issue will advance a broader discourse toward cultural struggle, empowerment, and possibility. This Theme Issue challenges First World hegemony, while recognizing the need for global collaboration in an ever-increasing global community. In essence, this Theme Issue brings to light the issues and challenges that educators and learners in developing countries address on daily basis. While science educators in developing countries must strive to enhance the educational opportunities available to all students, their real educational mission is often more closely associated with central tenets of social justice. In seeking to create improved contexts for educating learners, it is reasonable to raise our collective consciousness to the science, technology, and societal issues that ought to be addressed by all educators in the decades to come, thereby acknowledging that teaching for social justice is indeed a viable science education goal. Teaching for Social Justice The totality of an education in science is equally as much oriented toward social justice, critical democracy, empowerment, action-taking, and investing in our future’s intellectual capacity as it is about constructing conceptual understandings of the world. I recognize that there are individuals who state emphatically that this broader image is not what science education is all about. To such critics I offer the following imperatives: The essence of a learner’s education in science must be linked to an understanding of the nature of science and learners must be afforded the opportunity to experience the meaning of “education” in science education. I assert that we must transform how we see science education so that it is congruent with both how we see science and how we see education.

Science is about knowing. However, all knowing (therefore all conceptual thought—all theory, concept, and belief) leads to contradictions. One of the most profound problems with “Reality” is that it is changing—constantly. In essence, scientists’ search for knowledge is changing constantly as well. The search for knowledge—understanding the
world and the universe—is dynamic! In the context of this search for knowledge, scientists believe in an external world, simply because it is the task of scientists to observe the world “out there” so that conclusions about phenomenon may be drawn. Thus, the process of science is not a quest for absolute Truth or Reality; scientific knowledge is tentative and subject to change; and the practice of science rests upon a number of taken-for-granted metaphysical presuppositions about the external world.

How we see science is essential to how we construct our images of science education.

Education is about hope, dreams, aspirations, and struggle. Hope for a better life, dreams of what the world might be like, aspirations for future successes, and struggle over how to understand and overcome obstacles while searching for and achieving that better life. Education is about expanding upon the knowledge of lived experiences that learners bring to situations; it is about opening doors, opening minds, and opening possibilities. Education must be for something.

But what? Education ought to be for the purpose of fostering critical and participatory democracy, enabling students to recognize that the world that is being presented to them is in fact a world that is being made—it is changing constantly—thus, for this very reason, it can be changed, it can be transformed, and it can be reinvented. Education frees the mind to create the future. How we see education is equally as important to how we construct our images of science education. Life World Experiences and the Culture of Science How do these notions of science and education play out in society? As a result of an education in science, people in Western society are willing to accept what science “tells them” about the world and universe. Yet, they are also willing to accept that what is “known” can change, based upon future research and discoveries. Thus, people are willing to both accept what science “tells them” and at the same time they are equally willing to accept that what they have so easily accepted to be true may turn out to be false. How curious! Western popular culture today possesses images of science and scientists much like other cultures’ perceptions of village elders, medicine men, and shamans (ironically, the hegemony of Western science fails to view indigenous people’s knowledge of the natural world or their healing techniques as “science”). In the realm of Western popular culture, central tenets of science have become a belief system, people place their faith in science, they refer to the “miracles” and “wonders” of science, and they believe that the beliefs that scientists hold about the universe are true. Scientists are viewed as a source of wisdom. These notions of science and scientists are constructed in the context of the current K–12 science education experiences and life world experiences in Western society. Through these collective experiences, students and the general populace have no difficulty whatsoever constructing an image of “science knowledge” that often differs from knowledge used in their life world experiences.

Clearly, in the minds of the vast majority of the populace educated in Western society, the culture of science exists in the context of multiple subcultures and countercultures. Thus, I raise the following question: Have science educators been successful in their efforts to enable learners to construct scientific meaning in the context of the multiple subcultures in which they engage in life world experiences? I believe the simple answer to this question is “no.” For this read-256 KYLE son, I believe that the issues and challenges among science educators in Western and non-Western cultures alike are more similar than different. Ultimately, we must seek answers to the following questions: How do we come to see
science education in a context that will facilitate learners’ conceptualization of an ever-changing world?, and How do we facilitate the conceptualization of meaningful scientific knowledge?

**Knowledge and Science Education**

First, we must acknowledge that there exist inequities in our global community with respect to the social distribution of knowledge, as well as with respect to individual access to knowledge. Inequitable social distribution of knowledge and access to knowledge is not merely a phenomenon of non-Western cultures; such inequities exist within Western cultures as well.

The implication for science educators, however, is that the social construction and distribution of knowledge is plural; there is not a singular or universal knowledge. Rather, there are multiple knowledge’s. Thus, while everybody thinks, not everyone has access to the same knowledge and not everyone constructs the same meanings in the context of his or her life world experiences. Further, within each culture there are distinctive ways of processing and transmitting knowledge. If we view knowledge as plural, then it is only reasonable that the education in science that learners experience ought to be dynamic, it ought to be linked to one’s life world experiences, and it ought to focus upon the world and how we take action in the world. If the world is changing constantly, then an education in science ought to be focused upon the dynamics of change, the whole rather than the parts, and the ways in which individuals act in the world. Such an education in science would be very different from what learners experience today. Rather than focusing upon the whole, we have chosen to focus upon the parts; learners construct knowledge about the parts and never come to understand the whole or the ways in which highly specialized scientific knowledge is synthesized. Seldom does an education in science focus upon action, beliefs, or interactions, all in the context of striving to change, transform, and reinvent the world in an effort to create the future. The focus of an education in science ought to be upon an education that fosters learners’ ability to work collectively toward a better society. Such a focus would be in stark contrast to the ways in which learners come to know science through their science education experiences today. The science education that most learners have experienced actually serves to disenfranchise learners from coming to know the world and the universe. The science education that most learners have experienced is bound by disciplines and offers the impression of a static world.

When we view knowledge as plural, then the issues, concerns, and contextual realities raised by authors in this Theme Issue become the starting point for addressing the question: How can we create an education in science that is meaningful to all learners? I suggest that an education in science that is grounded in the context of development and sustainability would foster the kinds of global communication and collaboration that will be imperative in the forthcoming century. Addressing Poverty, Development, and Sustainability Poverty is a worldwide phenomenon. Poverty serves as one of the primary contributors to the inequitable social distribution of knowledge and the inequitable access to knowledge. Of all factors that combine to degrade health, poverty stands out for its overwhelming role. The World Health Organization views poverty as the world’s leading killer. Poverty affects health in its own EDITORIAL 257 right: Just being poor increases one’s risk of ill health. Poverty also contributes to disease and death through its second-
order effects; poor people, for instance, are more likely to live in an unhealthy environment. The interactions of disease agents, individual susceptibility, behavior (which often reflects education), and local environmental conditions all bear heavily on health outcomes. Poverty—not insufficient global food production—is the root cause of malnutrition. Poor families lack the economic, environmental, or social resources to purchase or produce enough food. We can no longer separate efforts to build an environmentally sustainable economy from efforts to meet the needs of the world’s poor. Understanding how poverty affects both the environment and health can enable policymakers and educators to identify new strategies for action. As we approach the forthcoming century, it is increasingly recognized both by governments and by corporations that there is a need for a new economic model—one that facilitates development and is environmentally sustainable. And, one that does not further exacerbate the widening gap between the “haves” and the “have-nots.” The defining feature of the 20th Century was growth grounded in the context of First World hegemony. In recent years, growth has become the de facto organizing principle for societies around the world. The place to begin a conversation on growth is with human population. In 1900 the world population was 1.6 billion. Total population reached 2 billion by 1930 and 3 billion by 1960. It only took 17 years to add another billion to the global population and a mere 12 years after that to reach a population of 5 billion in 1989. World population will surpass 6 billion this year. If population growth follows the United Nations world population projection, then we will add another 4.6 billion people in the forthcoming century. There will be a key difference in the 21st Century growth. During the 20th Century, growth occurred in both industrial and developing countries; during the forthcoming century, almost all the population increase will take place in developing countries—and mainly in urban centers. The population of the present-day industrial world is expected to decline slightly. The scientific and technological advances of the 20th Century can be described as phenomenal. The rapid pace of change can be seen in every field of human endeavor. Perhaps the defining economic development of the 20th Century is the harnessing of the energy in fossil fuels. In 1900, only a few thousand barrels of oil were used daily. By 1997, that figure had reached 72 million barrels per day. As we approach the 21st Century though, the key limits to sustainability are fresh water, forests, rangelands, oceanic fisheries, biological diversity, and the global atmosphere. In the forthcoming century we must recognize the natural limits of our behaviors and limit our environmental impact upon the world. An education in science must address the emerging issues of development and sustainability in a global context. One of the goals of the June 1992 Earth Summit in Rio de Janeiro was to forge a historic North–South partnership to help the world’s poorer countries make the transition to sustainable development. A key element of this new partnership was a pledge by industrial countries to increase their aid spending. Seven years later, little of the promised funding has materialized. However, a shift has occurred since the Earth Summit that is influencing prospects for sustainable Development: international private investment in and lending to developing countries. While there are numerous environmental concerns related to such private investment (especially since studies suggest that industries are generally drawn to the developing world by the low-cost of labor, the availability of natural resources, or the strategic access to new markets) international investment may bring cutting-edge environmental technologies to enable developing Countries to leapfrog over damaging
phases of the development path pioneered by the industrial world. Private capital is also
moving into the developing world as foreign direct investment (FDI) by transnational
corporations setting up local plants, often through joint ventures with lo- 258 KYLE cal
companies. FDI is the international capital flow of greatest significance for development,
as it is long-term and it has the added advantage of not contributing to a country’s debt
burden. People in developing countries lack access to many services crucial to a high
quality of life. For instance, 1.2 billion people—Z/b of humanity—have no access to
clean drinking water, 2 billion people have no electricity, and approximately 3 billion
people do not have adequate sanitation services. An important goal of developing country
governments is to provide these services to their citizens. Developing the infrastructure to
supply services such as electricity, transportation, and sewage treatment often involves
large construction projects that are costly both to national treasuries and to the health of
the natural world. An education in science should enhance developing countries’ future
citizenry’s capacity to find ways to provide these crucial services in ways that are
environmentally sound, socially equitable, and economically affordable. Throughout the
developing world there are numerous power projects now in the pipeline that potentially
have grave implications for the future health of the planet—especially for the quality of
the air and the stability of the climate. Over the next several decades, the bulk of new
global investment in the power sector is projected to take place in developing countries.
The world’s ability to avert a catastrophic global warming over the next several decades
will depend in no small measure on what kind of power plants are built. Traditional
environmental laws and enforcement systems need to be strengthened in many
developing countries. Innovations in national fiscal policy, such as reducing subsidies to
environmentally harmful activities and taxing them instead, are necessary as well. Policy
reforms that change incentive structures throughout national economies must be
implemented, thereby tipping the balance away from environment-

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Table 1

The 15 largest countries ranked according to population size: 1998, with projections for 2050
1998 2050

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Population (million)</th>
<th>Country</th>
<th>Population (million)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>1,255</td>
<td>India</td>
<td>1,533</td>
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<tr>
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<td>India</td>
<td>976</td>
<td>China</td>
<td>1,517</td>
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<tr>
<td>3</td>
<td>United States</td>
<td>274</td>
<td>Pakistan</td>
<td>357</td>
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<tr>
<td>4</td>
<td>Indonesia</td>
<td>207</td>
<td>United States</td>
<td>348</td>
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<tr>
<td>5</td>
<td>Brazil</td>
<td>165</td>
<td>Nigeria</td>
<td>339</td>
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<td>6</td>
<td>Russia</td>
<td>148</td>
<td>Indonesia</td>
<td>318</td>
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<td>Japan</td>
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<td>Bangladesh</td>
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<td>Nigeria</td>
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<tr>
<td>11</td>
<td>Mexico</td>
<td>96</td>
<td>The Congo</td>
<td>165</td>
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<tr>
<td>12</td>
<td>Germany</td>
<td>82</td>
<td>Mexico</td>
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<td>Viet Nam</td>
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<td>Philippines</td>
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<td>14</td>
<td>Iran</td>
<td>73</td>
<td>Viet Nam</td>
<td>130</td>
</tr>
</tbody>
</table>
9.3. Science Education in Pakistan

Education plays a vital role in human capital formation. It raises the productivity and efficiency of individuals and thus produces skilled manpower that is capable of leading the economy towards the path of sustainable economic development. Like many other developing countries, the situation of the education sector in Pakistan is not very encouraging. The low enrolment rates at the primary level, wide disparities between regions and gender, lack of trained teachers, deficiency of proper teaching materials and poor physical infrastructure of schools indicate the poor performance of this sector.

Education provides the bedrock for reducing poverty and enhancing social development. An educational system of poor quality may be one of the most important reasons why poor countries do not grow. In Pakistan, the quality of education has a declining trend. It is realized that science education in particular is reaching lowest ebb and needs to be improved urgently. There is acute shortage of teachers. Laboratories are poor and ill equipped and curriculum has little relevance to present day needs. The schools generally are not doing well. Tracing causative factors responsible for the present state is a critical need. These include defective curricula, dual medium of instruction at secondary level, poor quality of teachers, cheating in the examinations and overcrowded classrooms (Economic Survey of Pakistan, 2002). In Pakistan efforts have been made to mould the curriculum in accordance with our ideological, moral and cultural values as well as our national requirements in the fields of science, technology, medicine, engineering and agriculture, etc. The rise in supply of educational infrastructure or removal of the supply side constraints can play an important role in raising literacy and education of the population. Development budget allocation for the social sector has been very low throughout and is evident from the budgetary allocation for education.

9.4. Future Trends in Science Education

The importance of science education at different levels has been stressed by educators and researchers as it plays multiple roles in enhancing citizen’s scientific literacy, promoting the scientific and technological capacity of the workforce, and fostering next generation school science educators (NSF 1996; NRC 1997, 1999, 2000). Research in science education has been called to be conducted with an aim to critically “inform educational judgments and decisions in order to improve educational action” (Bassey 1995, p. 39) at different levels. It is critical not only to conduct relevant science education research to help science teachers improve their classroom practice and play better roles in enhancing scientific literacy, but also to understand what have been studied in the past in order to know what could be explored further in the future. This study applied automatic content analysis methods from scientometrics to investigate the
development trends of science education research. In particular, we proposed a multi-stage clustering technique based on bibliographic coupling to examine with what topics, to what development trends, and from whose contributions that the scientific journal publications constructed as a science education research field.

**Curriculum Reforms and Science Education**

The development of current research and curricular activities in science education can be traced back to the science education reforms in the late 1950’s in the USA (de Jung 2007; Fensham 2004). In his review, de Jung (2007) indicated that the three main waves of science education reform in the 1950, 1980, and 2000’s have shifted the foci of curriculum design and brought the evolution of science education research. The science education curriculum reform in the USA started with the recognition of the deficit of the nation in science and technology (de Jung 2007). The relatively low quality of science education was seen as the main cause of the nation’s inferiority to the former Soviet Union, who launched the first man-made satellite (Sputnik) in 1957. Instead of memorizing scientific facts, the major science curriculum reform efforts after Sputnik emphasized the understanding of basic scientific concepts and the process in learning science.

The second science curriculum reform in the 1980’s was brought by the alarming report, *A Nation at Risk* (National Commission on Excellence in Education 1983). The report warned that the USA had been falling behind in the international economic and industrial competitions because of the weaknesses in the educational system. As de Jong (2007) indicated, this wave of curriculum reform focused on turning the student’s passive school learning into an active process and connecting the learning of scientific concepts to their application in daily lives. Researches during this reform also focused on science learning as a conceptual change process.

The understanding of conceptions in science teaching and learning seemed to be overly emphasized after the early 1980’s. It was indicated that this approach may prevent students from linking their conceptual learning to the social and cultural context. The later evolution of constructivist views of learning has marked as the third wave of educational reform in the science education researches since late 1990’s (de Jong 2007; Jenkins 2001). As a result, social and cultural dimensions and the science-technology-society (STS) issues were brought into the scene of science curricula and research. In addition, new technologies such as computer-assisted instruction and the use of Internet also gained attention (de Jong 2007).

**The Development of Science Education as a Research Field**

Fensham (2004) used dimensions of structural, intra-research, and outcome in the judgment of the establishment of a discipline or a research field. In the structural dimension, Fensham (2004) indicated that a well established research field is: (1) to create the full professorial appointments to gain academic recognition; (2) to have research journals to publish quality research and report the research outcomes; (3) to found professional associations; (4) to hold research conferences periodically so that direct exchange and interaction among researchers can be made; (5) to establish research centers; and (6) to have research training plans to foster researchers.
For the dimension of professional association and research journals, studies have indicated that the USA was the first country to devote to science education research (Fensham 2004; Treagust 2006). For example, the first journal concentrating on research of science teaching and learning, *Science Education* (SE), was first published in 1916 in the USA. On the other hand, the worldwide acknowledged research association, the National Association for Research in Science Teaching (NARST), was founded in 1928 and still holds international conference annually. Sponsored by the NARST, the *Journal of Research in Science Teaching* (JRST) publishes 10 issues per year and has great impact on research in science education.

With the worldwide spread of journals on research of teaching and learning in science, science education as a distinctive field of research emerged and was developed internationally since mid-1900’s (Fensham 2004). Examples of the prominent science education research journals include JRST, SE in North America, *International Journal of Science Education* (IJSE, initially the European Journal of Science Education) in Europe, and *Research in Science Education* (RISE) in Australasia (White 1997).

One developing trend in science education research is that a wider range of countries were participating in research publication activities (Lee et al. 2009; Treagust 2006), which can be evidenced in the country’s level in the structural dimension (Fensham 2004). For example, as an active member in the international science education research community, it was not until the 1980’s that Taiwan started founding academic science education organizations and research institutes. In the 1990’s, publications from Taiwan researchers started to appear in the international English-language journals. Although the importance of science education had been brought to educational policymakers’ attention in the 1970’s, it took more than 30 years of gradually development for science education, as seen in the structural dimension (Fensham 2004), to be regarded as a research field in the educational institutions. For example, sponsored by the Ministry of Education of Taiwan, the science education center was established at the National Taiwan Normal University (NTNU) in 1974. Later in 1986, the institute of science education (graduate school) was founded at the NTNU and more graduate schools of science education have been established at other universities since. In the meantime, during the mid-1980’s, the Chinese association of science education (CASE) was founded and a CASE-sponsored science education conference was held annually. In 1993, sponsored by the CASE, the quarterly Chinese Journal of Science Education began to publish academic papers in the research of science education. It was then Taiwan’s participation in international academic activities in science education started. For international research journals, it was not until 1993 that the science education scholars from Taiwan published in journals of SE and JRST.

**Research in Science Education**

To understand how the research field has developed, researchers may investigate from a wide range of the structural perspectives such as educational reform movements (de Jung 2007) and the development level of the academic environment (Fensham 2004) to delineate the scope of science education research. On the other hand, using content analysis approach on literature review was also usually conducted to gain a more detailed
view of the development trends (e.g., de Jung 2007; Rennin 1998; Lee et al. 2009; Tsai and Win 2005; White 1997).

In comparing different editions of Handbook of Research on Teaching, White (1997) pointed out that research styles and research topics were two major changes in science education research since the second edition of the handbook published in 1973. In his study, a content analysis of journal articles was conducted to further examine the above observed changes. White (1997) used science education research articles in the Education Resources Information Center (ERIC) database and the journal RISE as sources of data. His analysis on research topics trends was done by counting the keywords of the articles from 1965 to 1995. The investigation of research style trends was across three decennial reference points of 1975, 1985, and 1995. The analysis concluded that science education research has shifted from laboratory-style experiments to observation and description of classroom practice while interviewing as research tool has become common.

With a focus on the quality of research, Rennin (1998) and Eye and Schmidt (2001) examined science education literature from the perspective of how to report research results and to improve research quality. After examining research articles published in the five journals of IJSE, JRST, RISE, SE, and Research in Science and Technological Education (RSTE) in 1996, Rennin (1998) illustrated and provided recommendations on how to present and improve the quality of quantitative research. Eye and Schmidt (2001) investigated the research trends in chemical education through a review of 81 studies published in the journals of JRST and IJSE from 1991 to 1997. As a result, quality criteria were suggested to include six categories: theory relatedness, quality of the research question, methods (for quantitative and qualitative studies), presentation and interpretation of results, implications for practice, and competence in chemistry.

In two time periods of 1998–2002 and 2003–2007, a series of content analysis comparing three major science education journals of IJSE, JRST, and SE were conducted (Lee et al. 2009; Tsai and Win 2005). In these studies, researchers’ nationalities, research types, and topics were analyzed and the trends were compared. It was indicated that researchers from the English-speaking countries contributed to most of the research products during the two time periods although the researchers from non-English speaking countries had increasing number of research articles, especially during the period of 2003–2007. As revealed, empirical study was the major research type during the two time periods while most of the empirical articles employed qualitative method in 2003-2007. In the studies, the research topics were categorized by the adapted NARST conference strand categories. The analysis found that the topics of “Learning-Context” and “Teaching” were gaining more attention from 1998 to 2007 while the topics of “Learning Conceptions” and “Culture, Social and Gender” were in decline.

De Jog (2007) also adapted conference themes, from the NARST and European Science Education Research Association (ESERA), as a pre-set framework to analyze research topics trends of science education for the 2 years of 1995 and 2005 in three selected journals of JRST, IJSE, and SE. The analysis revealed that the researches were becoming small-scaled in research design while more qualitative data collection methods were used. The top three research topics in 1995 were “students’ conceptions”, “practical work”, and
“teachers’ content knowledge.” In 2005, “practical work” was still in top three research topics, but “students’ conceptions” and “teachers’ content knowledge” were replaced by the topics of “teachers’ pedagogical content knowledge” and “STS and context-based issues.”

**Scientometrics on Research Trends of Science Education**

As seen from the above literature analysis, the reviews of science education research varied in purposes. There were researchers aiming to provide guidance for improving research quality (Eye and Schmidt 2001; Rennin 1998); while others focusing on identifying major features and contributors such as authors, topics, and research types (de Jog 2007; Lee et al. 2009; Tsai and Wen 2005; White 1997). In addition, attention was also paid to point out what have missed and might be done in future research (White 1997). Although various trends of science education research have been identified through literature reviews, variables such as researchers’ personal interests, level of professional knowledge, and use of traditional narrative review method could have led the reviews to subjective interpretations. Further, by using a pre-set category structure as analysis framework, the research topic ranking would depend on the category that the researchers choose to use (de Jog 2007). That is, different category structures could generate different topic ranking results when analyzing the same data.

To present a comprehensive and longitudinal overview, this study used the scientometrics method (Braun 2007) to conduct a development trends analysis of science education research. A total number of 3,039 articles from four of major science education research journals, namely IJSE, SE, JRST, and RISE, during the period from 1990 to 2007 were analyzed. With the application of the automatic content analysis method, this study analyzed the structure of science education research by identifying the major study topics, the development of research threads, the countries and the leading authors, and the most cited references on which the research community was formulated.

Instead of matching the articles reviewed with a pre-set topic structure, the research topic categories in this study were developed inductively as emerging from the entire corpus of the four journals from 1990 to 2007. This grounded approach took root on the materials to provide educators, researchers, and policymakers of science education an overview of the structure and evolution of the field. It was expected that this study would help educators and researchers reflect on the trends and issues in science education research, advance their understanding in science education, and pursue further exploration and practice in research and teaching. This study would also report on how automatic content analysis technique was used to explain and interpret the trends of science education research to yield information useful for further application of scientometrics in science education research.