



Natural Learning for a Knowledge- based India

The grassroot initiatives of promoting natural learning through open and flexible knowledge centers can liberate knowledge from the clutches of our rigid education structures and can be proactive steps of reforms towards a knowledge-based India.

MYRIAD mysteries of nature have unfolded over the years driven by the human urge for discovery. Physics has played a major role in this quest.

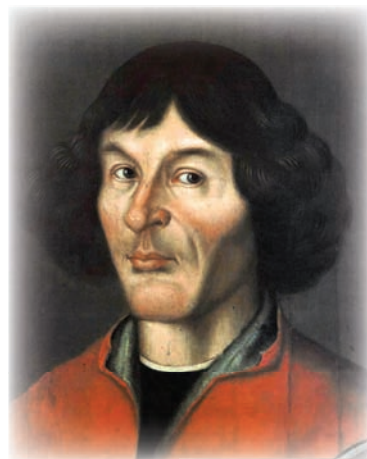
Aimed at understanding nature, physics evolved through the study of time, motion, matter and energy and systematic attempts to bring to fore the interrelations among them to unfold nature's underlying patterns.

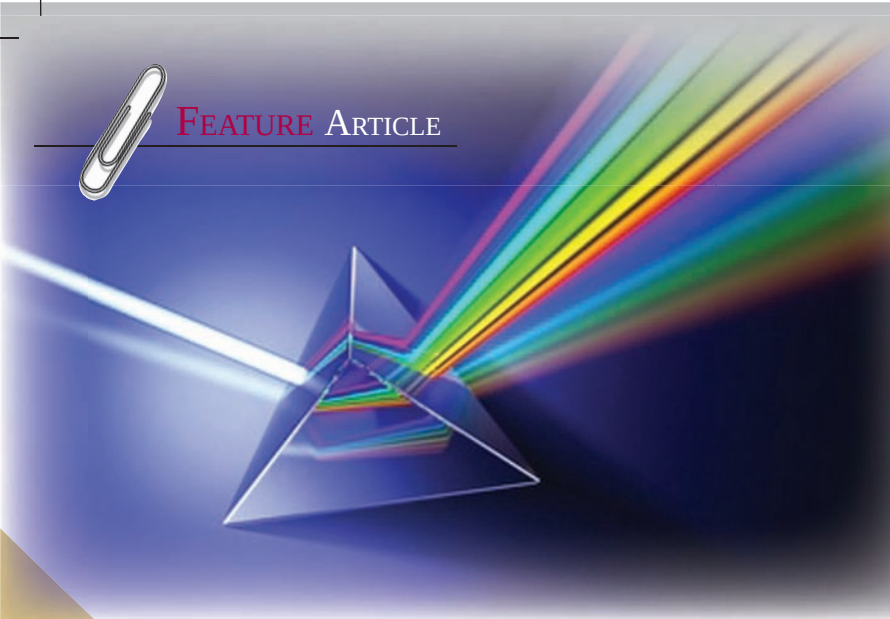
The ambitious goal of understanding nature in her totality guided physics to know not just what is seen or reached but also what is unseen and unreached covering extreme diversities like elementary particles and the largest superclusters of galaxies. It brought in its ambit three worlds – the macroworld in which we live, the unseen microworld and the unreached astronomical world. Countless researchers contributed to this evolution through myriad discoveries that decoded secrets of nature and brought to fore how nature 'thinks'.

The early natural philosophers who proposed models about nature included Thales who proclaimed that every event had a natural cause; Leucippus, Democritus and Epicurus who advocated the atomic point of view; and Aristotle and Archimedes who contributed to the understanding of mechanics in nature. The medieval period was mainly dominated by the influence of Aristotle's philosophy. The scientific method was introduced by Roger Bacon during this period as a repeating cycle of observation, hypothesis, experimentation and verification.

A major revolution in scientific thinking took place in the period between 15th to 17th century when Copernicus, Galileo, Kepler and others questioned the established ideas prevalent in astronomy during this period. This revolution culminated in the seminal work of Sir Isaac Newton at the end of the 17th century. Newton's contribution marks the inauguration of the age of reason.

Research work undertaken in the





older sciences known at that time such as optics, acoustics, thermodynamics, electricity and magnetism brought forth some interesting underlying features that were common to all these disciplines. In the mid 19th century, physics, as we understand in the modern sense of the term, emerged as a single discipline that could bind all these disciplines on the basis of these unifying features that came to be understood as the fundamental laws of physics that laid the foundation of physics.

Physics of the 19th century, which later came to be known as classical physics, answered questions of everyday life such as how objects around us rest or move (mechanics), how sound is produced and travels in different media (acoustics), how light behaves in various situations (optics), how heat flows in different situations (thermodynamics), what is the basis of electricity and magnetism and what are the causes behind various observed properties of matter.

By the end of the 19th century, it was felt that physics had discovered almost everything and matured as a near complete science. Lord Kelvin observed, "There is nothing new to be discovered in physics now, all that remains is

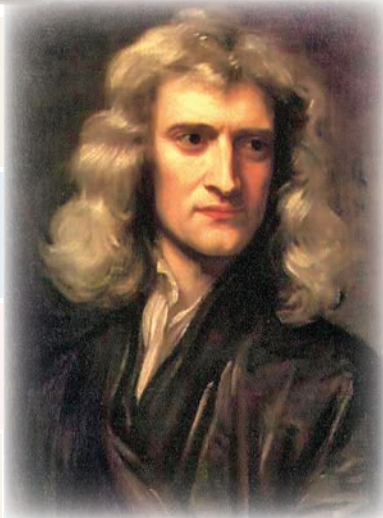
TABLE 1. UNIFICATIONS IN PHYSICS

In 1687, Newton unified celestial and terrestrial mechanics by showing that the same basic laws hold for astronomical objects and objects on the earth.

During 1820-30, Oersted and Faraday unified the then separate sciences of electricity and magnetism into that of electromagnetism.

In 1873, Maxwell showed that light is an electromagnetic wave thus unifying electromagnetism and optics.

During 1979-84, Glashow, Salam and Weinberg unified the electromagnetic force and the weak nuclear force into a single electroweak force.

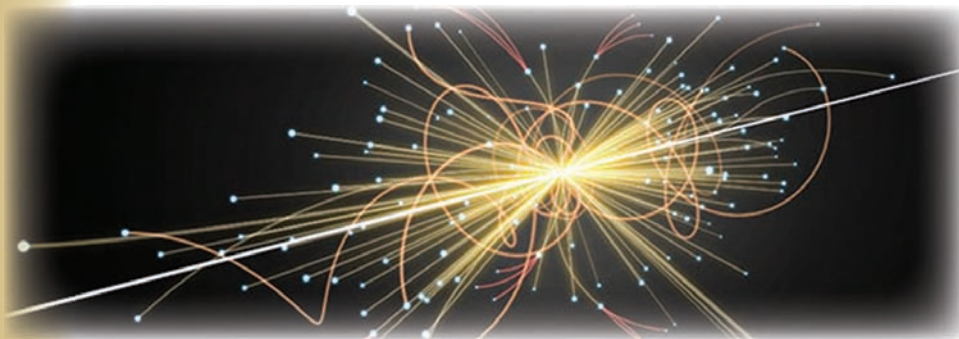


more and more precise measurement." However, this observation proved wrong in the beginning of the 20th century when some new experiments brought forth the failure of many ideas of classical physics on scales too small and too big compared to the domain of our everyday life.

These failures triggered new ideas and fresh insights that marked the beginning of another revolution in physics. Physics of the 20th century, known as modern physics, comprises mainly of quantum physics and

relativity. Quantum physics is the physics of the microworld, the world of electrons, neutrons, photons and a host of other elementary constituents. Relativity is the physics of the cosmic world, the outer world of stars, planets and other celestial objects that are very massive and travel with great speeds, comparable to that of light.

However, all through these pursuits the evolution of physics was guided by the aim to unify the various observed natural phenomena on the basis of their common fundamental features. For example, the root cause of the observation that certain rocks (loadstone) were attracted to one another was understood as magnetism. Similarly, electricity was understood to be at the root of the observation that objects such as amber when rubbed with fur would show similar attraction between the two. However, further research revealed that these two forces were just two different aspects of the same force –





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"...what is the source of knowledge? Where do the laws that are to be tested come from? Experiment, itself, helps to produce these laws, in the sense that it gives us hints. But also needed is imagination to create from these hints the great generalizations ... to guess at the wonderful, simple, but very strange patterns beneath them all, and then to experiment to check again whether we have made the right guess."

Richard Feynman (*The Feynman Lectures on Physics*, Vol. 1, Addison-Wesley (1963), p. 1)

electromagnetic force.

Thus, physics connected natural phenomena to their root causes and then also connected these causes together. Einstein's dream of unifying all fundamental forces of nature into a single force could not be realized during his lifetime. However, these attempts are continuing through research in areas such as GUT (grand unification theories) and TOE (theory of everything).

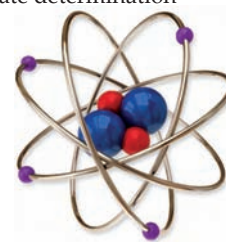
Fascinating Journey of Physics

The evolution of physics is a fascinating account of its long journey dotted with eureka moments of thousands of researchers and of discoveries that came to us as shining pearls in the ocean of knowledge.

physics is like probing the method in the madness of nature. Richard Feynman describes it using the analogy of the game of chess. Nature around us may be likened to be a grand game of chess. The myriad happenings around us are like moves played by nature. Understanding nature means watching this game in order to bring forth the basic rules that govern these moves. The rules that stand the tests of experimentation and consistency with existing well-established science evolve as the laws of physics. These laws are expressed with economy and precision in the language of mathematics and serve to understand the grand chess of nature. Mathematics provides a compact and exact language to describe the order in nature.

Laws of physics are often termed

as laws of nature as they represent the intelligence and predictability in nature. So, all that takes place in nature is in accordance with these laws and anything that is disallowed by these laws can't be a reality of nature. Thus, the laws of physics equip us with the power of prediction; they facilitate determination of the future on the basis of the data about the present. For example, Newton's laws enable accurate prediction of the state of motion of a body at any future instant if the forces acting on the body and the initial conditions are known.

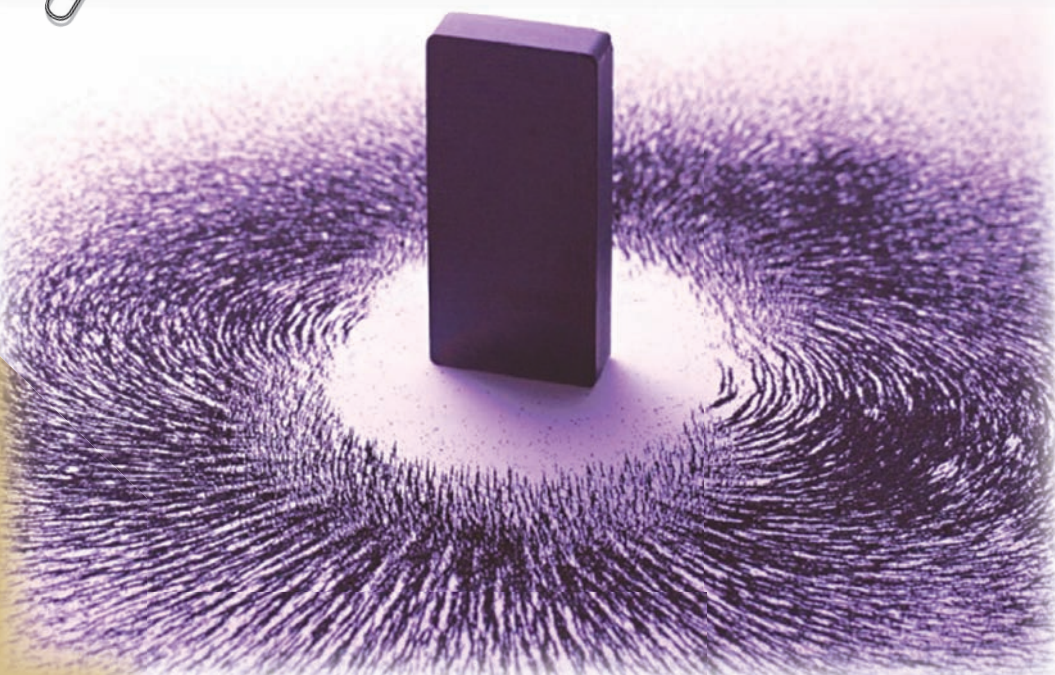


The fundamental laws in physics

Discovering the basic laws of

TABLE 2. EXAMPLES OF RESEARCH OUTPUTS OF CURIOUS QUESTIONS AND THEIR APPLICATIONS

Curious question	Research output	Field of application
Newton wondered why objects thrown up came down. Einstein probed deeper into this question.	Newton's theory of gravitation, Einstein's theory of gravitation	Rocketry, Space Technology
Coulomb asked how charges attract and repel each other. Oersted wanted to know why a magnetic needle kept near a current carrying wire deflects.	Coulomb's law of electrostatics, Theory of electromagnetism	Electrical engineering
Huygen and Maxwell were inspired to know what light is.	Electromagnetic wave theory of light	Telecommunication engineering
Young was interested to understand how light waves interfere. Fresnel was curious to know why light bends round sharp obstacles.	Theory of interference and diffraction of light waves	Interferometry and Diffractometry
Einstein was interested in knowing why electrons come out when light falls on certain metals and probed into how coherent light could be produced.	Quantum theory of light, Theory of stimulated emission of light	Optoelectronics, Photonics, Quantum optics, Laser technology
Raman was inquisitive to know why light passing through a transparent medium undergoes a change in frequency.	Raman effect	Raman spectrophotometry, Raman scanning techniques



are only a few signifying the inherent simplicity of nature. The vastness of physics is due to the myriad applications of these basic laws to a large variety of complex systems in nature.

History of physics convinces us that discoveries are more often results of open enquiries and curious insights into nature and not due to some pre-biased, pre-targeted research. For example, Ampere, Coulomb, Voltas, Ohm, Faraday, Tesla and other pioneers in the field of electricity and magnetism did not aim their research at energizing

the world; they were just satisfying their natural curiosity.

Limitations of Structured Learning

The process of acquiring knowledge, that is, learning, has been traditionally implemented through education structures like schools and colleges. However, the role and design of these structures in facilitating and optimizing learning has always been a subject of debate and discussion and quite often

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it is accepted that knowledge provided through these structures leaves much to be desired in fulfilling the needs of one's career and life.

We know that distance is the product of speed and time. Thus with increased speed one can cover more distance in less time. On the other hand with slower speeds one requires more time to cover the same distance. Comparing distance with learning goals and speed with a complex combination of natural propensity and competence based on knowledge and skills, one can find that structured learning compels everyone to reach the same distance in the same time despite widely varying natural speeds.

Thus, the present system comprising of a rigid syllabi, stereotype examination patterns and results based on marks scored in examinations forces a 'one size fits all' approach and smothers individuality. The system goes through a sort of 'pushing syndrome' where students are pushed ahead on the basis of marks considering these as 'official statements' of knowledge and competence. The system thus turns out too many educated and too few knowledgeable products.

Several studies and reports have thus questioned whether knowledge can be synonymous to education with the present system. Table 3 includes some relevant statistics and observations in this regard.

The rigid walls of disciplines, syllabi, examinations, marks, and degrees in these structures are cracking under the pressure of today's knowledge-based world. This is witnessed in the growing emphasis on non-formal and

Table 3. STATISTICS AND OBSERVATIONS ABOUT THE LIMITATIONS OF THE PRESENT SYSTEM

Patents per million population	Researchers per 10, 000 labour force
South Korea 4451	UK 79
Japan 3716	US 79
Germany 2288	Russia 58
US 910	China 18
India 17	India 4
http://www.nature.com/news/india-by-the-numbers-1.17519	
75% engineering students in India are unemployable. (www.thehindu.com/business/75-percent-indian-engineering...)	
• Out of the 48 countries studied, India ranks second last in the U21 rankings of national higher education systems.	
• The relative impact of citations for India is 0.51, which is about half of that of the world average (1.0).	
("Higher Education in India: Vision 2030", www.ey.com/.../EYHigher-education-in-India-Vision-2030.pdf)	

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predictability in nature and is in consonance with the objectives and evolution of physics discussed above. So, the speed decides the time and distance in natural learning instead of the fixed distance and time forced in structured learning. The system based on natural learning thus adjusts to individuality and promotes a win-all situation.

We may call the places that facilitate such learning as “knowledge centers” to distinguish them from the available “education centers”. The syllabi of knowledge centers may be considered in the form of open and flexible knowledge spirals. The depth of a knowledge spiral signifies the knowledge accumulated

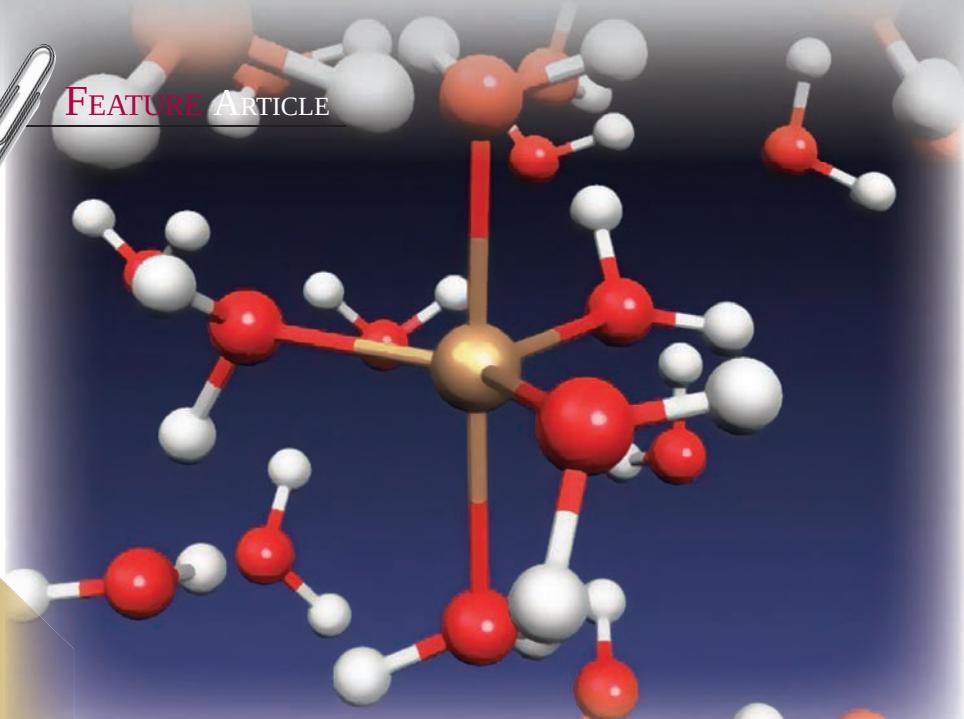
through research and the circular area at a particular depth represents the breadth of knowledge at that depth, i.e., the applicability of the knowledge available at that depth for industry or self-employment.

All curricular physics and physics used in industry constitute the breadth of physics whereas new knowledge brought forth through research constitutes the depth of physics. Large number of books, courses and industries related to physics convince us of the vast breadth of physics and the intense research carried out in physics that is disseminated through research journals and conferences remind us of the great depth of physics.

The knowledge dug through the depth of the spiral gets well established over the years and gradually becomes the breadth of the spiral. For example, Einstein's work on photoelectric effect was published in a research journal in 1905. Thus photoelectric effect was considered an area of research in the first quarter of the last century. In later years it was studied in the curriculum of post graduation. Today it is studied at the undergraduate or the pre-college level.

The journey towards gaining knowledge may begin with everyday curious observations or enquiries

Level	Response to the question what is common salt and what it contains
School student	Chemical compound called sodium chloride – dissolves in water, known as NaCl, forms due to ionic bonding of electropositive Na and electronegative Cl...
College student	Crystalline material belonging FCC lattice structure, NaCl structure energetically favoured, energy of cohesion...
Research student	Two-ion quantum mechanical system, linear combination of atomic orbitals, properties, central, non central forces, second, third and higher order elastic constants...



Physics embodies an enquiry into the folded logic of nature. The more layers we unfold by reason, the more layers emerge out confronting us with the vast, unending reserves of nature's knowledge.

of natural phenomena and can then proceed through their refinement to various knowledge domains indicated by different petals of the spiral based on the interests and needs of the learners. The journey advances to more and more complex aspects, current advances and research. The journey can take several routes like breadth to further breadth, breadth to depth, breadth to depth to further breadth and so on giving learners the freedom and facilities of entry, exit and comeback.

As the learners keep climbing the spiral by augmenting their quota of knowledge they find ample scope in both the breadth and the depth of the spiral for pursuit of their natural propensities. Infinite depth and breadth of nature's knowledge has the capacity to accommodate everyone. Each entity of nature contains infinite knowledge and thus learning in this way becomes an unending process. Table 4 illustrates this with an everyday example of common salt.

These responses bring us back to the question, "what is common salt and what does it contain". It contains knowledge, infinite knowledge! The learner takes knowledge from the salt as per his/her capacity.

Scope of Natural Learning

The scope of natural learning encompasses the entire world of matter and energy. Matter and energy are interdependent and interconvertible and their countless interactions result in myriad natural phenomena that we observe around us. These phenomena aroused the curiosity of scientists and led to scientific discoveries.

The omnipresent role of physics is evident if we just glance around, observe an entity and explore it a bit. If the entity is a solid and makes us curious about what makes a solid and how various solids differ we are in the realm of solid-state physics. If it is a rock we are led to petrophysics and clouds lead us to cloud physics. Looking beyond the skies takes us to the realm of space physics and astrophysics and looking into the fathomless seas leads us to branches like ocean physics and naval acoustics. Moving objects take us to dynamics and those at rest to statics. Our interest in 'nothing' leads us to the domain of vacuum physics.

Physics embodies an enquiry into the folded logic of nature. The more layers we unfold by reason, the more layers emerge out confronting us with the vast, unending reserves of nature's knowledge. The exploration becomes a bottomless search; the more we know the more we come to know that there is much more still to know.

The journey towards gaining knowledge may begin with everyday curious observations or enquiries of natural phenomena and can then proceed through their refinement to various knowledge domains.

Towards a Knowledge-based India

Today we are living in a knowledge era. The growth of a knowledge-based world is signified by a marked shift from our dependence on natural resources to knowledge-based resources. This is because natural resources are limited and are consumed when utilized whereas knowledge is not lost when given away and one can have knowledge without depriving others of it. On the contrary, knowledge expands when shared.

India is determinedly marching towards this goal. The vision and mission 2020 of late Dr. APJ Kalam generated a lot of excitement. Then there are some initiatives such as the National Knowledge Commission (NKC), National Mission on Education Through Information and Communication Technology (NMEICT), INSPIRE (Innovation in Science Pursuit for Inspired Research) and the Village Knowledge Center project of the M.S. Swaminathan Research Foundation that are addressing the goal of a knowledge society. But they are woefully short for a country of the size, diversity and youth demography of India.

The grassroot initiatives of promoting natural learning through open and flexible knowledge centers can liberate knowledge from the clutches of our rigid education structures and can be sure and proactive steps of reforms towards a knowledge-based India. Through such reforms basic physics, as a natural philosophy, promises to make us a knowledgeable nation, applied physics, a developed nation and metaphysics, a noble nation.

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