Teaching the 'principles of science' within a liberal arts curriculum

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The question of developing and teaching a foundation course in science within a liberal arts curriculum is examined through lived experience. I discuss and analyse the formulation of the course and its structure, contents and functions. This is based on my experience of teaching the course for two semesters to liberal arts undergraduates. This article aims to invoke inquiry to understand the basis of science and scientific methods, the nature of science, the criteria of scientificity and the dynamics of scientific rationality at various stages of human history. Science is examined from different perspectives in the humanities and social sciences to find their inter-relatedness. The humanities, in particular history and philosophy, play an important role in examining science and scientific methods in order to understand the limitations of science. Finally, the need for integrating science and humanities in contemporary education is discussed.

Keywords: Contemporary education, foundation course, liberal arts, principles of science.

ACQUIRING knowledge through education[1,2], whether affordable or not, is a universal necessity today. One chooses higher studies and good education to gain a better job, a better profession, improved career prospects and better quality of life[3]. Over time, methods of knowledge impartment, as well as educational systems, evolve. There is a long but direct line connecting the simple techniques of knowledge generation employed by prehistoric hunter–gatherers to the present advanced knowledge systems that we employ[2–5]. Layered on this are the different aspects of technical and professional skills, such as the use of telecommunication and information technologies that have made the world into a small local community[6].

There is a worldwide realization that the different educational systems across the world are interdependent and interconnected[3]. There is a felt need for a system that is liberal and inclusive of different aspects[4,5], and diverse communities have increasingly adopted this system of education around the globe[5].

The idea of liberal education can trace its origin to the Greeks and the Romans[7]. The word 'liberal', derived from the Latin word 'liberalis', means 'the quality or state of being free'. The ancient Greeks and Romans formalized liberal arts education into a system where seven disciplines were put together into the trivium and the quadrivium. The trivium had grammar, logic and rhetoric, while the quadrivium had arithmetic, geometry, music and astronomy. However, this does not mean that other countries did not have a liberal educational system. Almost every great civilization of the world had its system of education to meet the needs and demands of the times, and India is no exception[8].

Post independence India has had three significant education policies in 1968, 1986 and 2020 (refs 9–11). As we all know, education is well linked to nation-building, and this mission became active in setting up of a National Education Commission under D. S. Kothari in 1964 (ref. 9). The purpose of the Commission was to examine all aspects of the educational sector, and suggest policies and procedures for the development of education in the country. The Kothari report strongly recommended the need for science and technology (S&T) education in nation-building and leveraging productivity in various sectors. Likewise, the second policy also continues its emphasis on S&T in the promotion and strengthening of national growth, progress and integrity[10]. This focus area became the backbone of the nation-building process. The efforts of high-quality academicians, scientists, doctors and engineers were strongly encouraged. Their fundamental contributions are visible in the various renowned universities, institutions and research laboratories that they have established.

However, the recent problems and issues of the 21st century about the recent pandemic, public health issues, food security, healthy food supply, clean water, clean energy, environmental degradation and climate change are quite complex and challenging to manage by knowledge from S&T alone. In such situations, there is a dire

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need of experts from both the sciences and social sciences for finding feasible solutions. The conventional discipline-based education system as departments in universities, institutions, and colleges is not generally conducive to develop feasible solutions of the contemporary issues. For this, collective consciousness and cooperation among different disciplines is a practical way out for a successful solution. It will also provide synergistic support from different disciplinary experts with a desirable resultant effect.

In July 2020, the Government of India announced and released the final version of the National Education Policy (NEP) 2020 (ref. 11). This new education policy aims to bring transformational reforms in schools and the higher education system in the country. There will be no rigid boundaries between arts and sciences, curricular and extra-curricular activities, vocational and academic streams at both school and higher education sectors to promote a holistic education. In chapter 11 of NEP 2020 titled 'Towards a more holistic and multidisciplinary education', there is a strong emphasis to revive, promote and deliver the liberal arts, multidisciplinary education and vocational skills in education systems, where humanities and arts are given equal weightage to science, technology, engineering and mathematics (STEM)[11]. It also aims to make liberal education as a foundation course for undergraduate programmes. From the academic session of 2020, liberal education needs to be imparted in higher education and research programmes in India.

Imparting liberal education is one of the aspirations of 21st-century education across the world, and this can only be achieved by co-evolving the sciences with the humanities and the arts. At present, liberal education is implemented extensively in USA, especially in Ivy League universities[4,5].

The Association of American Colleges and Universities defines liberal education as follows:

> 'Liberal education is an approach to learning that empowers individuals and prepares them to deal with complexity, diversity, and change. It provides students with a broad knowledge of the wider world (e.g. science, culture and society) as well as in-depth study in a specific area of interest. A liberal education helps students develop a sense of social responsibility, as well as strong and transferable intellectual and practical skills such as communication, analytical and problem-solving skills, and a demonstrated ability to apply knowledge and skills in a real-world setting.'

It is now widely held that one of the primary purposes of liberal education is the production of vibrant, creative, innovative, rational, and productive global citizens[4,5]. Increasingly, new curricula foster interdisciplinarity, cutting across boundaries of natural sciences, social sciences, and humanities. Thus, the idea of liberal education has been gaining momentum in India as well[12], despite the presence of more conventional degrees at the undergraduate level. In the last few decades, considerable efforts have been made by engineering and management institutions of India to incorporate humanities and social sciences courses in their curriculum. The case of recognizing the environmental science foundation course as a compulsory core course for all the undergraduate students in India follows the new guidelines of the University Grant Commission (UGC)[13]. The inclusion of the environmental science foundation course is an example of interdisciplinary education under the motive of liberal education.

Interdisciplinarity is the integration of disciplines that inspire a work, a discovery, or the production of new knowledge[14]. In a way, interdisciplinarity itself is the diversity in aspirations or motivations to do or imagine something unique. Because of the integration of various disciplines, the impact of interdisciplinary studies (or work) can diffuse across disciplines to interact with each other, producing synergistic output. For instance, in the discovery of the ozone holes, knowledge contribution came from various fields such as Earth science, social sciences, and chemistry[15]. In the case of multidisciplinarity, a group of people with different disciplinary backgrounds work together to solve a problem using their specialized skills. Under multidisciplinary, separate disciplines come together, but they maintain the distinctive characteristics of the respective individual subjects. However, in the case of interdisciplinary work, scientists from different disciplines are well informed of the significant developments in other fields, and this becomes an advantage when one's knowledge in a field hits the blind spot. Moreover, the extent of interaction across disciplines under interdisciplinarity is more significant because there is a synthesis of different approaches to something unique. A broad education at the undergraduate level allows expanding one's horizon to understand science, society and culture in a better and effective way[3–5]. Therefore, in the light of NEP 2020 (ref. 11), there is a need to revise undergraduate and postgraduate courses to provide comprehensive interdisciplinary and multidisciplinary education.

Interdisciplinary and multidisciplinary education stresses and acknowledges the importance of different disciplines and their associated values in the process of knowledge production. The value of these approaches can also be seen in analogy with different communities present in a society, where different ideologies and cultures play different as well as complementary roles in bringing solidarity among the members of the society in which they live; yet they maintain a distinctiveness of their own. The criteria of interdisciplinarity is also noticeable in the social network relationship where every member shares a mutual relationship agreeing with the whole is often more significant than the sum of its parts.

The 21st century has seen rapid changes not only in S&T, but also in society, culture, politics, environment, and public health. This continuous change has modified how we think about ourselves and fellow members of society, including other species on this planet. Amidst the uncertainty of these times, how do we face the present and future challenges? To go with the ever-changing flow of modernity and to adapt successfully, we need to learn continuously, need creativity, lateral thinking, social responsibility, cultural sensitivity, and above all, practical communication skills. These form the basis of what a liberal education delivers[3,4].

The foundation course

I developed and taught a foundation course in science titled 'principles of science (PoS)' to liberal arts undergraduate students of Ashoka University, Sonipat during the academic session 2016–17. Foundation courses are essential components of liberal academic education. Through these courses, students are exposed to a wide range of subjects at the basic level, to help them prepare for more advanced study. Every undergraduate at Ashoka University is expected to take seven foundation courses. At that time, these were: Great books, Indian civilization, Literature and the world, Mind and behaviour, Social and political formations, Quantitative reasoning and mathematical thinking, and PoS.

The task to simultaneously develop and teach a science foundation course was extremely challenging. First, the composition of the class was diverse and heterogeneous. The course could be taken by students in any year, depending upon the subject combination and interest. This was taxing since the course transaction was made at the convenience of three different levels of students at a given point in time. Secondly, almost 70% of the students were social science and humanities majors. Thirdly, it was clear that considerable work had to be done to overcome a false dichotomy developed in the minds of most students, that the sciences and the humanities are non-overlapping fields of knowledge.

I have studied physics as a major during my undergraduate and post-graduate education at the University of Delhi and did a PhD in physics at Jawaharlal Nehru University, New Delhi. When I began my professional career as a researcher and teacher, I knew little about liberal arts education. For the last four years or so, I have continuously interacted and discussed with several people regarding the pedagogy of science teaching for liberal arts education and scientific epistemology to understand its purpose and related issues. My teaching experience has been at the Central University of Rajasthan, Ashoka University and the University of Delhi. During this academic journey, I have been able to experience the environment of different types of institutions, and have interacted with students and teachers from a variety of backgrounds and intellectual levels. This experience has allowed me to reflect on the purpose of science education for undergraduates in contemporary times, and in particular, the importance and value of the course PoS.

A foundation course in science, to be meaningful to students pursuing a liberal arts education has to address the 'Science versus non-science' issue – a contentious and polarizing distinction[16]. In the next section, the approach that I adopted is discussed.

Principles of science

Science is one of the foundational pillars of modern civilization, education, and democracy, as pointed out by Galileo[17]. He said,

> 'In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual.'

This statement illustrates that no idea, theory, or an established system is sacred and beyond challenge. Through careful observations of celestial motions using telescopes, Galileo reasoned and demonstrated the truth of the heliocentric model of Copernicus over the Ptolemaic system of a geocentric universe[17], that the Earth revolves around the Sun. He not only brought a change in an established system, which was accepted as truth for about 1500 years, but it plays an essential role in taking the 'principles of science' as a way of understanding our natural and social worlds.

The usefulness and power of science lie in the systematic methods that can be adopted and practiced by anyone. It is often asserted that science is entirely objective because of the use of mathematics, but such a claim is more authoritative than scientific. In this context, it becomes essential to note that science relies on the inductive process, where general statements are made based on a few observations. This sometimes makes scientific methods fuzzy since inductive studies can never be always correct throughout time and space. In the early 20th century, physical science embraced relativity and uncertainty in the formulation of theories. Just like the field of literature, humanities and arts, scientific knowledge came from our efforts, experiences and imaginations. There is an inverse relationship between the objectivity of scientific knowledge and the necessity of experiences. The more we focus our view on the objectivity of science, the less we see the need for our experience, and vice versa. Nonetheless, our experiences and imaginations are just as fundamental as a physical reality in formulating scientific knowledge.

Until the Renaissance, humanities and science were unified under the discipline of natural philosophy in the Western world. However, due to various socio-economic factors and politics, a gradual divide occurred in the educational system. In 1953, Snow[16] identified this issue as 'the two cultures' in which the world of physical scientists and literary intellectuals became standalone fields of knowledge. Since then, subjects like sociology, anthropology, political science, economics and psychology formed a 'third culture' called 'social sciences' to understand our societies and human nature[18]. In the developing and underdeveloped countries, subjects like arts, humanities and social sciences are undervalued since it is believed that these disciplines do not contribute to the economic growth of a country.

The mental divide between the sciences, humanities and social sciences are strongly present in the minds of contemporary young students who have had conventional systems of disciplinary education. Therefore, it is essential to address the issue of this mental gap and introduce a buffer like science education as a liberal arts component. It has become crucial to illustrate that science has its philosophical and historical accounts of trials, failure, hope, discovery and excitement. Many of our findings and new ideas in science are the result of the contestation of different ideas and thoughts. Topics like climate change or the application of S&T in our societies are always complex, controversial and contested with different ideas.

The move to interdisciplinarity and multidisciplinary has to be initiated as a choice to create common ground across various disciplines. So, it is always better and necessary to build a conceptual understanding of the basis of science that most students are familiar with already. Around this understanding, topics about the scientific methods, philosophical foundations and the history of science will help in shaping the desired objectives. The PoS course aims to train the students from various disciplines to observe, analyse, experiment, think and argue critically on various phenomena, including the affairs of everyday life.

To introduce some of the interconnectedness of ideas that might not come across at the secondary level of education, the PoS course includes the following modules:

> Methodology of science; history and philosophy of science; principles of relativity and the quantum revolution foundations of biological enquiry; climate: physical, social and cultural aspects; and Science, technology and society.

The process of science has been crucial in establishing standard methods to study the natural world and to derive knowledge that can be regarded as reliable and genuine[19]. I therefore chose to start the course with the question, 'What is science and how does it work?' This is mainly to examine the open nature of the scientific quest from different perspectives. It also made it possible to consider significant historical and philosophical developments of ideas about our universe, matter, atoms, nature of light, the origin and diversity of life forms, biodiversity, changes in climate and the role of science in society.

The course structure and contents were thematically arranged, as given in the above template. Teachers who are interested in teaching this course or similar types courses can improvize the above template. In this process, the same structure can be retained, or subsequent changes can be made by bringing new sets of examples and explanations appropriate to the need of the hour. It is also possible that a departure from core focus areas of this course mentioned in the form of the thematic areas might come up with time. However, the rigour should be in the similar logic of interdisciplinary and multidisciplinary education. This course framework may help everyone as the beginners of a new curriculum on liberal education.

Methodology of science

The components of observation, extraction of regularities, formulation of theories, experimentation, prediction and finally, observation of those predictions, roughly speaking, constitute the scientific method. Acquiring this practice can, in general, help develop critical thinking. One of the most influential personages in the history of science, Isaac Newton, wrote[20]:

> 'Scientific method refers to the body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical, and measurable evidence subject to specific principles of reasoning'.

Knowledge about our natural and social world is gathered systematically through scientific methods. The separation into different 'subjects' is a consequence of the kinds of questions that are posed. Physics, the study of nature, may well have begun with the evolution of humankind through observations of the physical world and its components. By this time, we have learned a great deal about the fundamental features of the universe and how it came into being due to the Big Bang that was believed to occur about 13 billion years ago. Thereafter, the creation of matter, the fundamental particles, atoms and molecules, eventually gave rise to chemistry. Our solar system and the earth formed 4.5 billion years ago, and at some time, about a billion years later, the first living organism was formed; biological sciences address these issues. Evolution, in particular, our own evolution and the interrelatedness of all living organisms on the earth is an important aspect of this field of inquiry. As humans began to form societies, cultures and languages also evolved, and fields like sociology give knowledge and insight into various aspects of human society, social relationships and behaviour. At the same time, anthropology aims to uncover the past, present and future humans and human culture.

The attempts to classify and systematize are central to the scientific enterprise, as philosophers like Alex Rosenberg ('Science, like other human activities, is one response to our need to understand the world')[21], Bohr ('The task to science is both to extend the range of our experience and to reduce it to order')[22] and Hampel ('Science is ultimately intended to systematize the data of our experience')[23] have pointed out. Scientists, as well as philosophers, seek to gather systematic knowledge about nature and its components. Such activities lead to the formulation of laws of nature, statements that express the regularities of the natural and social world as precisely as possible. By using natural laws, science provides us explanations of natural phenomenon that we see in our everyday life and predictions of things that are unknown to us. Each generation tries to construct a framework of knowledge about events that might have happened in the past, monitors the current situation, and aims to forecast the future. In the first few lectures of the course, this framework is presented and discussed.

History and philosophy of science

In many traditional academic institutions, subjects like history, philosophy, and science are pursued separately as non-overlapping disciplines[16]. In universities such as Utrecht, The Netherlands, though, the practice of pursuing 'history and philosophy of science' (HPS) as an interdisciplinary subject has been institutionalized for a long time now. From the assessment of such activities and its subsequent outcome, scholars like Dijksterhuis[24], Kuhn[25], and many others have agreed upon the idea that academic training through HPS can bridge the gap that exists between the humanities and science. Even though the practice of experiments and mathematical treatment constitutes the basis of the modern scientific method, advances and developments of science, when viewed through a historical lens, are primarily continuous human affairs that arise from human reactions and experiences as a result of culture, traditions, norms and ideas across time and space.

From this perspective, science is considered as an enterprise of secular reason and knowledge about the natural and social world with a tradition of historical context and philosophical accounts[25–27]. HPS is the epistemological laboratory of science[24]. Through this, we can understand the past and present science and the associated underlying system of thoughts and self-correcting practices that were used in deriving scientific knowledge. At the same time, questions from the philosophy of science help us understand the foundations of scientific knowledge, standards of validity, testability and pragmatic position of science and its limitations.

The occurrence of a false dichotomy between the sciences and humanities in academics is due to various factors like the accelerated pace of science, standardization of methods and techniques, and developments of experiments that confirm predictions. When confronted with differences, humans tend to create mental barriers, perceiving contradiction wherein there might be complementarity. The 'principle of complementarity', developed by Niels Bohr, is central to understanding how physical and social realities work. It provides a tool to tackle dichotomous and contradictory situations. In a simplified form, this principle asserts that different ways of looking at reality can both be right, but not at the same time. An example from the natural world is that light is neither inherently a particle nor a wave. It can be either one of them, depending on how we measure it. The concept of particle and wave offers complementary perspectives on the reality of light. In a similar vein, it is crucial to view that science and humanities complement each other. No doubt, there are differences between natural sciences and humanities in terms of primary interests, methods, sources of evidence, criteria of beauty, etc.

The success of the theory of relativity (Einstein), and the work on logic and mathematics (Russel and Hilbert) at the beginning of the 19th century, inspired a group of physicists and philosophers (the Vienna circle) to work together towards building of the foundation of science. They viewed science as cumulative knowledge based on logic and mathematics, and the surest path to truth, discounting human factors and interpretations. Because of this view, the rift between science and humanities reached a peak in the 1930s. Popper, who was a member of the Vienna circle, had challenged the idea that scientific knowledge inferred beyond facts (inductivism) can be falsified[28]. He argued that one cannot prove a scientific hypothesis like mathematics conjecture, but can falsify them. Popper introduced the idea of testability of hypothesis or theories, and it remains a crucial component in science and its methods. A theory must be falsifiable to be scientific, and the process of falsification provides a criterion to differentiate between scientific and unscientific theories.

Snow's 1959 Rede lecture, 'The two cultures' addressed the intellectual fragmentation resulting from the dichotomy between the world of literary intellectuals and the world of physical scientists[16]. It was widely thought that lack of scientific knowledge was not an important issue to the achievement of success in the areas of governance, politics, business, media, or arts. There was (and is) a severe problem when educated people who are in a leadership role are unaware of the developments brought by S&T; this has resulted in impoverished public policies in the past. At the same time, it has also become important for scientists to realize that science cannot be independent of social, cultural and political developments.

The year 1962 witnessed a change in the intellectual realm with the publication of Kuhn's *The Structure of Scientific Revolutions*[25]. It gave a new dimension of understanding the nature of science. By drawing inspiration from studies of psychology about the stages of cognitive development in children, Kuhn proposed features about the developmental stages of the sciences. His insight, that scientific practices are tightly interwoven with a pattern of historical tradition, and that one can unfold the pattern of changes in scientific activities by studying its history remains important to this day.

In the introduction of *Structure*[25], Kuhn wrote about the importance of the history of science:

> 'History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed.'

He saw that a field of study matures by forming a paradigm, a set of guiding concepts, theories and methods accepted by the community. Within that paradigm researchers pursue what can be termed 'normal science', expanding the paradigm gradually by articulating, modifying, developing, and extending its range of applications. Over time, findings that differ from expectations or predictions, namely anomalies, accumulate and the field enters a state of crisis where old established theories collapse. At this point, confidence in the existing paradigm breaks down and there is a need for radical change(s). A new paradigm needs to be set up to address, accommodate and explain the set of accumulated anomalies. A scientific revolution occurs when there is a discontinuous shift from an old paradigm to a new one, and the whole process repeating with a new phase of normal science. This idea of a repetitive pattern of scientific activity displaced the conventional ideas about cumulative scientific progress. And, Kuhn's *Structure* remains one of the most influential titles in the humanities and social sciences.

Paradigm shifts in biological sciences

While the field of biology is vast, one of the most important concepts that needs to be conveyed within the PoS course is that of evolution. As Theodosius Dobzhansky famously[29] said: 'Nothing in biology makes sense except in the light of evolution'.

Darwinism and Mendelism are two important paradigm shifts in biology that brought new thoughts and ideas to solve the 'mystery of mysteries', namely how living species originate and transmit information of life from one generation to another. Evolution by natural selection, the process through which all diversity of life arose was discovered independently by Darwin and Wallace. This fundamental principle of biology was identified through careful observation by studying plants and animals species methodically and in different environments. The theory of evolution constitutes one of the most important revolutions in the history of science and has had an immeasurable impact and not just in biology. However, there was one missing point, and it could not explain how characteristics were passed on from one generation to the next. This missing link was discovered by Mendel, who propounded the 'principles of inheritance', making it a vital paradigm shift in biological science. Based on his experiments on peas, Mendel proposed the idea of genes (which he called factors) to account for the transfer of characteristics from parents to offspring. This principle is considered as the basis of modern genetics.

Questions concerning the origin of life, evolution, the diversity of life forms, heredity – many deep issues remain a puzzle. Nick Lane[30], a biochemist at University College London, wrote: 'There is a black hole in the heart of biology'. A discussion on some of these key ideas is essential, mainly since these notions pervade so much of modern thought in a variety of disciplines.

Weathering climate change

Climate change is a good topic through which students can be exposed to the complexity of the science–society interface. Much debated, climate change is the battleground of scientists from varied disciplines, philosophers, politicians and corporations. Various physical changes such as global warming, rise in sea level, melting of ice sheet in Greenland, etc. indicate that climate change is a real phenomenon, but there are disagreements about the accuracy of data and integrity of scientists who are publishing different reports on it. Cultural interpretations about the economic needs and political ambitions of different countries further complicate the issue. The failure to respect global agreements (Paris and Kyoto accords, for instance) by various developed countries, indicates the political and economic complexities involved in combating climate change.

It can be argued that the change in climate itself is not a problem which requires a solution every time[31]; rather it is a phenomenon of environment, culture and politics that provides a challenge in interpreting various relationships, and in getting creative and innovative ideas to tackle such issues. Science may help unlock the mysteries of the physical aspects of climate, but understanding the implications and the meaning of climate change may require other inputs. The idea of climate change evolves as societies and nations find new ways of using it to fulfil their needs.

In the winter of 2016, New Delhi faced a severe environmental hazard and health crisis. Toxic haze blanketed the area. There were several reports about difficulties in breathing and schools were closed. A combination of vehicular pollution, crop burning in the neighbouring states, and climatic conditions have all conspired to create an environmental problem of this magnitude. The causes of the problem are thus tightly intertwined in physical, social, economic and cultural issues. Knowledge of atmospheric, environmental and biological sciences is essential, but it also requires knowledge of socio-cultural, economic and political aspects, and management skills to find a long-term solution.

How do we attempt to find long-term solutions to such problems? Discussions in the PoS classroom engage the entire cross-section of students since each brings different skills to the table, and this topic gives an excellent opportunity to demonstrate the importance of science within the liberal arts curriculum.

Science, technology and society

The PoS course helps underscore the close relationship between science and humanities for both undergraduate and postgraduate education[3]. An understanding of natural sciences, social sciences and humanities and their close association is vital in contemporary education when the aim is to prepare the current generation of college-goers to face the challenges of the future. In a post-industrial and post-modern world, a broader education across the natural sciences, social sciences and humanities is essential[3,5]; specialized or conventional forms of education are ineffective while facing most of the contemporary issues and challenges.

In addition to addressing educational needs in contemporary times, PoS helps cultivate valuable qualities of the mind such as creativity, imagination, and cultural sensitivity. It confers a sense of social responsibility by making it possible to examine science from the perspectives of arts, aesthetics, humanities and social sciences[32]. Such understanding of the development of science through humanistic perspective enables students understand the scientific, technological and social issues in their entirety.

Summary and conclusion

> ‘The clashing point of two subjects, two disciplines, two cultures – of two galaxies, so far as that goes – ought to produce creative chances. In the history of mental activity that has been where some of the breakthrough came. The chances are there now’.
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> – C. P. Snow[16]

Historically, great ideas have emerged at the intersection of science and humanities. Therefore, rather than introducing the basics of science as a series of facts, a humanities-rich version of science is more beneficial and engaging. Besides, there is an intellectual growth in gaining perspective on how scientific method or thinking works. The historical and philosophical approach provides us a degree of subjectivity and space to think about multiple perspectives.

Traditionally, education is specialized, with science and engineering being given more importance compared to the disciplines of humanities and arts, mainly because they change our natural world and rapidly affect how the society functions. The downside to this has been that science teaching at all levels has followed a thematic approach with defined objective goals, highlighting progress and its achievements. Subjects are taught in a prescriptive manner with questions and strategies to find exact knowledge or answers. Engineering institutions and business schools do have courses on ethics and philosophy, but they are not given much importance. Little attention is paid to socio-cultural and philosophical issues, glossing over the fact that social conditions drove many scientific developments, and those driving forces came from trade and commerce, war, medicine, arts, religion and human curiosity.

Technical education, to a great extent, is necessary for an industrial-based society to continue to exist and develop further. At the same time, post-industrial and postmodern societies need to cultivate long-term leadership potential and skills such as cultural sensitivity, critical thinking and adaptability. Reforms in education that echo Snow’s concerns have taken place, with influential journals such as *Science* stating that a humanities-rich understanding of science makes good scientists and that it benefits both natural and social scientists. The best technologists have long recognized this: Steve Jobs spoke about Apple’s philosophy (Apple iPad 2 Keynote, Special Event, March 2011):

> ‘It is in Apple’s DNA that technology alone is not enough – it’s technology married with liberal arts, married with the humanities, that yields us the results that make our heart sing.’

The world today faces pressing problems – pandemic, poverty, diseases, unemployment, loss of biodiversity, sources of energy, environmental hazards, pollution and climate change – all of which are threatening to life on the earth. The combined force of S&T alone is ineffective in solving the major problems faced by humanity if there is a lack of social responsibility among the people. To tackle such issues, one needs to understand and engage with socio-cultural aspects[4].

At present, a narrow specialization or a single perspective does not give the intellectual flexibility required to cope with a rapidly changing world in a complex and uncertain manner. As mentioned in the NEP 2020 (ref. 11), it is necessary to develop multiple perspectives to relook, reshape and reframe the pathways we think and understand about ourselves and others[33]. For this, there is a need for intellectual training that is feasible and adaptive to address the problems and questions we currently face. Therefore, it is vital to integrate the sciences, social sciences, and humanities in contemporary education[3].

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