A unified quality assurance system for engineering education: an exploratory viewpoint

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ABSTRACT: Education in general, and engineering education in particular, remain the basic foundation of any civilised society. However, the present world, despite glorious scientific and technological advancements, is unable to cope with the problem of stress and strife that lead to quantum increases in criminal offences among the educated masses. In the article, the authors attempt to reveal evidence of education in various civilisations of the ancients, brick by brick, in a summarised form and explore the reason for the present restlessness in society. They also try to explore the possibilities of bridging this gulf between peace and restlessness through a conceptualised unified quality assurance system for engineering education and to establish objectives of such a quality assurance model. In the article, the authors also develop the concept of evaluating the status of a given engineering education system through a drishti-chakra conceptualisation. A practical case is also illustrated for two engineering institutions in Agra in India.

THE ELEMENT OF EDUCATION: ITS EXISTENTIAL SEARCH THROUGH THE AGES

Education is the basic foundation for any civilised society. It changes the face of the nation and plays a crucial role in its development. Education is the prime agent to bring about desirable modifications in the knowledge, skills, culture and sensitivity of human beings [1]. Despite this, it cannot be denied that human history contains as much progress as regression. Further, *newer* does not always mean *better*, and *later* not necessarily *newer* [2]. Hence, it becomes necessary to explore and understand the existential nature of education through the ages before attempting to speak anything about elements of quality in the present educational system in general, and engineering education in particular.

History is replete with evidence of education of some kind, either formal or informal, being present in various old civilisations like Roman, Mesopotamian, Egyptian, Harappan, Mayan, Greek, etc. Most had their own script and literature engraved either on walls or processed and preserved leaves and tree bark.

The technique of preserving a dead body in the form of mummies in the pyramids of ancient Egypt is still a matter of investigation among experts. Ancient Indian literature reveals the fact that education and training in various skills used to be imparted to the pupils in India through the mode of gurukuls/ ashrams and gurus.

Definitions of the key elements are as follows:

- *Ashrams*: A form of residential school;
- *Gurus*: A competent teacher;
- *Veda*: Knowledge and teachings;
- *Vedangas*: Different part of knowledge like Upanishid, etc;
- *Chanda*: A systematic arrangement of alphabets in a stepwise fashion with a pattern of works placed grammatically that have a meaningful sense and style of poetic presentation;
- *Kalpa*: A scale to subdivide entropic time;
- *Nirutta*: Contradiction, basically pertaining to logic and hypothesis.

It would not be out of place to quote the following statement of a renowned speaker of uncommon wisdom from the scientific community during his presidential address to university students on the occasion of the Indian Republic Day ceremony on 26 January 2003:

> *Indian civilisation and culture is very ancient. The first Indian painting is evidenced on stones and is expected to date back about 40,000 years from the present. From the ancient times, liberal scientific investigation has been the hallmark of Indian tradition, which has been inherent in veda and vedangas, kalpa, education, chanda, nirutta, grammar and astrology. Our scientists have given enough from the ages. This not only includes the symbol zero but also many hypotheses and principles. About 2,500 years ago, during the time of Panini and Pingal, who according to Indian tradition have been considered as brothers, the Indian mathematical science (Vedic mathematics) was at its peak and pinnacle. Panini gave such a grammar in Sanskrit, which is considered to have enough computing efficiency equivalent to the most efficient computing machines of today, and that there is no language in the world that has its parallel. Pingal described for the first time the binary number system almost during the same period* [3].
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> (translation by the authors)

The above statement supports the fact that a well-developed educational system must have been present even in ancient times. Later, there came a gap, but the skill and philosophies did not die out. The skill of Arjun (the prince and son of King Pandu of Hastinapur, presently near Delhi) in the area of warfare (the art of archery) is well known.

However, during the time of great emperor Ashok, which dates back to 269-239 BC, Takshashila and Nalanda came to be recognised the greatest universities of their time in the area of literature, art, astronomy and shilpa-shastra (craftsmanship). Scholars from all over the world used to come to enlighten themselves in different schools of thought. In Japan, even in the Edo era (ie start of the 17th Century), the level of education was by no means low. The Shogunate government established specialised schools focusing primarily on the teaching of Chinese classics (Confucian studies) to the progenies of Samurai warriors. These specialised private schools used to be called *fief* and *terakoya* [4].

Time went by and the use of machines was founded by Anderson in Glasgow around 1790 and Brickback in London in 1823 to impart general education to craftsmen and artisans. Anderson's University ultimately became the Royal Technical College, Glasgow, Scotland, UK. France started technical education at about the same time. In the USA, the oldest surviving technical institute is the Renselaer Polytechnic Institute at Troy (New York State), which was founded in 1823 and started giving degrees in civil engineering in 1835. Germany started late, but developed after the Franco-Prussian war a chain of technological institutes (culminating in the *technische hochschule*), which provide teaching to all grades of people [5].

The presence of great engineering marvels in the form of monuments is a living example of the technological innovations of olden times. The pyramids of Egypt, Great Wall of China, temple of Angkor Wat, Sun temple at Konark, caves of Ajanta and Elora, plus the fineness and symmetry in the temple structures at Khujraho, are nothing but the rampant outcome of so-called marvels of *technovation* of that time, which was devoid of automation as is present today. This clearly shows that technological advancement existed even in those days.

However, present-day education/higher education has emerged out of various politico-cultural changes in different pockets of the world. In 1868, a political revolution took place in Japan, marked by the collapse of the political power held by the Tokugawa Shogunate, which had long dominated Japan as the head of the samurai warrior class, and the birth of a new system of political authority with the Emperor as its head. The beginning of the modernisation of Japan can be seen in this revolution, known as the Meiji Restoration [4]. The first formalised engineering education in Canada was given at the University of New Brunswick around the mid-1800s. Since then, the diversity of courses in engineering has increased enormously [6].

India has the second largest number of engineering students in the world [7]. In India, the first industrial school was established at Guindy, Madras, in 1842 and the first engineering college named as Thomsan Engineering College at Roorkee in Uttar Pradesh was established in 1847. Credit for starting degree classes in mechanical and electrical engineering and in metallurgy belongs to the University of Banaras (1917). In Dayal Bagh, Agra, a technical college came into existence in 1930 to impart diploma level training in automobile, electrical and mechanical technology [5]. The setting up of Delhi Polytechnic in 1940 (later Delhi College of Engineering), the College of Technology at Guindy, Madras, in 1944 and the Engineering College at Dayal Bagh, Agra, in 1950, along with engineering colleges at other various places, took the lead in fulfilling the requirements of the Indian technical workforce to grow and sustain pre-dependent and post-independent India in order to realise the dream of India as a growing industrial economy [8][9]. The above exposition establishes the fact that education in general, and engineering education in particular, remained the major driving element, besides the socio-political aspect, in the advancement of society at large.

CRIME VIS-À-VIS THE EDUCATED MASSES

The status of different technical institutions in different parts of globe in the present time is far more advanced. Despite technical advancements and the information boom in the area of information technology being witnessed today, there have been sharply growing incidences of various types of crimes at all levels being committed by so-called educated persons over the past few years.

For example, in his review of corruption by professionals in the USA, Shakantu points out that construction industry has been inevitably the harbouring ground of corruption, including extortion, bribery, fraud, theft and even bid rigging [10]. Elsewhere in the world, cases of corruption among technocrats abound. Examples include the following:

- In Manhattan, the District Attorney's office announced in October 1999 that 31 architects, real estate brokers and managers plus 24 construction companies had pleaded guilty to bribery charges related to bid rigging on construction projects;
- In Guangzhou, China, 205 officials in the construction sector were charged with bribery between January and June 2002;
- In Thailand, massive corruption was found in the awarding of Thailand's new Nong Ngu Hao Airport and were reported in 2002;
- There are serious levels of corruption in the USA, UK, Japan, Canada, Greece, Germany and Turkey. This has forced the World Economic Forum governors for engineering and construction to form a multinational taskforce to work closely with international transparency and form an international and independent anti-corruption organisation, and to develop anticorruption principles to guide companies that participate in engineering and construction procurements around the world [10];
- A recent report in 2005, from the Indo-Asian News Service, state that the Anti-Corruption Branch of the Government of India snared 233 corrupt officials, up from 161 in 1999. It further added that an official of the Military Engineering Service (MES), plus an additional director of the Directorate of Revenue Intelligence, have also been arrested for demanding and/or accepting bribes [11].

Such a situation is certainly alarming and raises the question as to why educational advancement of such a higher level in the area of technology and sciences could not keep the young, educated, intelligent and skilled human resource emotionally stable. Still, it is believed that education acts as a catalytic factor to produce skilled workers and imparts progressive outlooks to its citizen [3]. Further, higher education faces new challenges as a consequence of the growing global market, and rapid social and technological evolution encourages competitiveness. The budget is another factor that needs to be increased for education [12].

In view of the above facts and dilemmas, it seems that there exists an imminent need to examine education in general, and technical education in particular, so as to develop a society of an emotionally balanced technical workforce, rather than just a simply intelligent technical workforce. Therefore, this necessitates an examination of the issues from philosophical and societal points of view.

SOME SOCIO-PHILOSOPHICAL ASPECTS

There are certain key voices in educational philosophy, who have significantly contributed to clarifying the basic understanding of what education is and can be. They have also provided powerful and critical perspectives that reveal certain problems in education. A bird's eye view of the observation of some selected few is enumerated below.

Albert Einstein pointed out that knowledge must continually be renewed by ceaseless effort if it is not to be lost. He also advocated that the school has always been the most important means of transferring the wealth of tradition from one generation to the next. The continuance and health of human society is, therefore, still highly dependent on schools than it was formerly [13]. Jean Jacques Rousseau stated that everything we do not have at our birth and which is needed when we are grown up is given to us by education [14]. Nietzsche emphasised that the teacher is a necessary evil [13]. Plato advocated that a sound education system can only produce citizens of a sound character [15]. Good education, according to M.K. Gandhi, is that which draws out and stimulates the spiritual, intellectual and physical faculties of children [16]. Radhakrishnan explained that the education is not a process of pumping information into empty containers. The true end of education is not the acquisition of information, important though it may be, or the acquisition of technical skills, although they are essential in modern society. One must have that superior outlook that goes beyond information and technical skills.

The purpose of all education is to provide a coherent picture of the universe and an integrated way of life [16]. One must obtain this through a sense of perspective, a synoptic vision and a samanvya of the different items of knowledge. Radhakrishnan further emphasised the following:

> *We are building a civilisation, not a factory or workshop, the quality of civilisation depends not on the material, equipment or political machinery but on the character of the man. The major task of education is improvement of character* [16].

On one occasion, while speaking at the convocation as Guest of Honour at Agra University in 1935, on the plight and backward condition of India, the saint and philosopher His Holiness, Sir Sahabji Maharaj, pointed out that education is the only solution to improving the present state of India. He spoke thusly:

> *Education, more education, education made perfect is the only panacea for our country's ills and evils: It is only then, that would India produce its Tagores and RadhaKrishnans, its Boses and Tatas, its Sulaimans and Saprus, in plenty; and would its merchants and manufacturers, directors and technicians, scientists and inventors, financiers and investors, collaborate in freeing the country from poverty and disease and raising it to its proper place of honour in the polity of nations: and would its statesmen and politicians, and legislators and public workers unite heads and hearts to devise ways and means to bridge over the wide gulf that at present divides the hearts of the rulers and the ruled; and, last of all, would its universities function in the fullest sense of form* [17].

The thought-provoking ideas on education expressed by various philosophers and saints as stated above has one thing in common, ie that value based education should be given emphasis provided that humanity wants to evolve itself to a superior hierarchical level of consciousness to bring peace and harmony along with the materialistic development.

The education process should be a continuous value-based process, which must bring out the latent potentiality to be applied within a framework of a spiritual, physical and philosophical environment for the uplifting and development of humankind. Therefore, it must train the human brain to take up the societal problems of the world in the most humanistic way. Education might be called a designing and developing tool of humankind, which shapes men and women, children and the young, middle-aged and old alike in order to satisfy the needs of society along with their own needs within the means of available resources for sustainable development. It is the way of optimising human ability and can, therefore, assume the status of a Human Activity System (HAS).

DIFFERENT MONITORING SYSTEMS FOR ENGINEERING EDUCATION: A BRIEF OVERVIEW

It now becomes imperative to explore the functioning of systems of technical education as is present today in different parts of the globe, for example the Accreditation Board of Engineering and Technology (ABET) and its predecessor, the Engineering Council for Professional Development, have been responsible for quality in engineering education in the USA since 1932. ABET is a federation of 28 professional engineering and technical societies that have joined together to promote and enhance engineering and applied science education in the USA [18].

The engineering profession in Canada is highly regulated through 12 provincial and territorial associations of professional engineers. Each association is charged with the responsibility to regulate the practice of engineering in the interest of, and for the safety and protection of, the public through special acts of legislature. Engineering is, therefore, a self-regulated profession in Canada [19].

In Europe, the core activities of the European Society for Engineering Education (SEFI) are undertaken just like the American Society for Engineering Education (ASEE) through numerous working groups that concentrate on specific areas of interest and organise periodic meetings, seminars and conferences. The overall message from Europe is that the education of engineers is changing rapidly from the traditional chalk-and-talk approach to one that emphasises understanding, as well as the acquisition of knowledge through an increasing level of involvement in project-based and problem-based activities [20].

In Australia, the Institution of Engineers, Australia (IEAust) is the professional and accrediting body. The Australian Council of Engineering, Deans and the Academy of Technological Sciences and Engineering decided that a fundamental review of engineering education in Australia had to be undertaken as a matter of urgency. The need for leadership, teamwork, concern for the environment and other important issues of higher education has been emphasised [21].

Jordan plays a leading role in running profit making universities in the Middle East. The Council of Higher Education (CHE) is considered for two forms of accreditation: the general accreditation of the university and departmental or programme-oriented accreditation [22].

Established on 19 November 1999, the Japan Accreditation Board for Engineering Education (JABEE), a nongovernmental organisation, examines and accredits programmes in engineering education in close cooperation with engineering associations and societies [23][24].

In September 1999, the Education Commission began a review of the entire Hong Kong education system and issued a proposal for reforms of the academic structure, curricula and assessment mechanisms at all levels of education [18].

Chinese engineering and technology have developed rapidly since the founding of the People's Republic of China in 1949. The Chinese Academy of Engineering (CAE) was established in 1994. It is a legally certified and independent corporation and currently has 439 members. It works in collaboration with the Chinese Academy of Sciences, the Chinese Academy of Social Sciences, as well as the industrial and education communities. CAE members provide advice on major national construction projects and on the development of Chinese engineering and technological enterprises [25].

In India, the National Policy on Education (NPE) of 1986 and its programme of action (1992) advocates a National System of Education in the country, which would ensure that up to a given level, all students – irrespective of caste, creed, location or gender – have access to education of a comparable quality and common standards [26]. The National Board of Accreditation of the All India Council for Technical Education (AICTE) aims to bring standards of some of the programmes offered in institutions on par with programmes in technical institutions in the USA and Europe by introducing a quality auditing system, and establishing a datum for measuring the quality and excellence in engineering education [7].

The great demand for technical education and the need to enhance the quality and relevance to meet the changing industrial requirements calls for alternative delivery modes. Distance and Web-based connectivity are features that have to be exploited in the given competitive arena.

THE CRUX OF THE PROBLEM

The above exposition regarding education in general, and engineering education in particular, makes it very clear that problems do not actually lie in a particular system or its arrangement, but are embedded in the style and working of the drivers who propel the system. What has happened actually is that, over the last few decades, society has consistently started favouring science over religion, competition over cooperation, exploitation over conservation and acquisition over distribution. This results in a profound cultural imbalance that is the root cause of the problem of the present emotional imbalance, egocentric attitudes and higher incidences of criminal offences, even among the educated masses.

Therefore, it becomes obvious for drivers to comprehend in some scientific manner, the status or scenario of a particular engineering education system under consideration. This is not an easy task. However, it would not be out of place to submit a policy statement in the form of a definition of quality engineering education, as deliberated by the US National Science Foundation (NSF) taskforce on Total Quality Management (TQM) [27]. Two such statements are as follows:

- *Quality engineering education is the development of intellectual skills and knowledge that will equip graduates to contribute to society through productive and satisfying engineering careers as innovators, decision-makers and leaders in the global economy of the 21st Century*;
- *Quality engineering education demands a process of continuous improvement of and dramatic innovation in student, employer and societal satisfaction by systematically and collectively evaluating and refining the system, practices and culture of engineering education institutions* [27].

Innovation, a productive and satisfying career, system refinements, continuous improvement and refinement in the culture of engineering education are the keywords that could be underscored in the above definition. These elements should deliver the needed impact on the societal development of any nation, irrespective of its economic background. Although it also talks about culture in engineering education, it fails to take into account the question of peace, harmony, humane thinking and the achievement of superior consciousness, which should redeem the world from the shackles of selfishness, avarice and greed, etc, along with developments in technical areas, in order to lead the world in a unified yet modular manner towards the goals of comfort, social justice, techno-socio advancement and tranquillity of mind. It is only then that one can think about crime reduction among the educated masses and it is only then that tensions will cease to exist.

Nobel laureate, Prof. Richard Ernst, while delivering his recent lecture on the topic titled *Academic Opportunity of Conceiving and Shaping our Future* at the University of Landau in Germany at the 55th Meeting of Nobel Laureates stated that *Dayalbagh Educational Institute is unique university in the world where science and spirituality are going together and where professors and students work in the field together*.

In this context, the model of the education system (including engineering and technical), as developed and practiced at Dayalbagh Educational Institute (DEI), Dayalbagh, India, for more than two decades now, is worth mentioning. It talks about developing a *complete human* (defined and visualised as a set of several elements) as a well-rounded personality.

If the concepts delivered by the above system and the one deliberated by the US National Science Foundation (NSF) taskforce on TQM, as well as others, are integrated and logically modified in a holistic manner, then a better model may facilitate wholism, harmony with a higher consciousness, modularity, pragmatism, technovation and excellence as its hallmarks.

Since interactive management provides a general and flexible framework for conducting a process of inquiry to assist groups of participants to deal with complex issues, a set of 15 domain experts, who were derived from academia, government departments in the planning and administration of education, finance and industries, including the authors, were selected on the basis of a second generation system design paradigm, which supports a consensus-driven interactive-iterative process in order to develop a robust model. The methodology of content analysis and Nominal Group Technique (NGT) has, therefore, been utilised so as to obtain overall integrated descriptive elements for the status review of an engineering education system [28][29].

Three workshop sessions in two stages were organised in order to prepare an integrated list of elements. During the first stage, several lists of elements for better quality engineering education were prepared from primary and secondary sources. This included the Accreditation Board for Engineering and Technology (ABET) and the National Science Foundation (NSF), both in the USA, the Institution of Engineers, Australia (IEAust), the European Society for Engineering Education (SEFI) and a progress report on education in Dayalbagh, Agra, India (1915-2005). These compiled lists were further clarified, merged, edited, coded and keyworded into three lists, as agreed upon by domain experts. The first included elements from DEI (Code DE), the second consisted of a combination of the others and were coded as US-European-Australian-Asian Combine (USEAAC), while the third consisted of additional elements that domain experts considered as necessary, which was coded as AE. In all, 91 elements have been considered.

Furthermore, seven important aspects from the point of view of the quality of engineering education were identified and agreed upon by domain experts as necessary dimensions. These comprised the following:

- Organisational and Physical Aspects (OPA);
- Foundation Courses (FC);
- Sociocultural Aspects (SCA);
- Spiritual-Ethical and Moral Values (SEMV);
- Personality Traits and Attributes (PTA);
- Professional and Academic Skills (PAS);
- Employment Potential (EP).

The elements of the above three lists were categorised and placed into their respective dimension by the domain experts. A list of the dimensional categorisation is given in Table 1.

In the second stage of the exercise, the domain experts were called upon to rank the elements using NGT. The use of NGT incorporated asking the domain experts to identify at least three elements that they considered to be most important out of each identified dimensions from among the three lists of elements in an integrated manner.

For this purpose, the following trigger question was posed to them:

> *Which of the elements according to you has the greatest potential for its positive or negative impact on the quality status of an engineering education system? Give a list of three of each type ranked in order of intensity of their potential impact.*

A sample response sheet is shown in Table 2.

Table 1: Dimensional placement of the key elements.

SN	Dimension	Element	No. of Elements
1	Organisational and Physical Aspects (OPA)	USEAAC: 8,9,12,16,18 DE:1,2,3,4,6,8,9,10,11,12,13,15,16,34,35,36,37,38,39, 40,41,42,44,45,46,48,52,54 AE: 1,2,3,4,12,13,14,15,16	43
2	Foundation Courses (FC)	USEAAC:10 DE:17,18,19,20,21	6
3	Sociocultural Aspects (SCA)	DE:14,22,23,24,25,30,31,32,47,49	10
4	Spiritual-Ethical and Moral Values (SEMV)	USEAAC:5,6,15,17 DE:26,27,29,33	8
5	Personality Traits and Attributes (PTA)	USEAAC: 7 DE:7,28,50,51,56,57	7
6	Professional and Academic Skills (PAS)	USEAAC:1,2,3,4,11,13, DE:5,43,53,55	9
7	Employment Potential (EP)	USEAAC-14 AE:5,6,7,8,9,10,11	8
	Total		91

Table 2: Sample response sheet for the NGT exercise.

Dimension	Positive Impact				
	I	II	III	IV	V
Organisational and Physical Aspects (OPA)	DE-45	E-12	USEAAC12	-	-
Foundation Courses (FC)	DE-17	DE-20	-	DE-21	-
Sociocultural Aspects (SCA)	DE-23		DE-22	-	DE-47
Spiritual-Ethical and Moral Values (SEMV)	USEAAC6	-	-	DE-29	USEAAC5
Personality Traits and Attributes (PTA)	USEAAC7	DE-56	DE-7	-	-
Professional and Academic Skills (PAS)	USEAAC1	USEAAC3	DE-5	-	-
Employment Potential (EP)	E-6	E-10	USEAAC14	-	-

Positive or negative impacts recorded by the domain experts were tabulated and totalled up, ignoring the sign. Those elements that bore no vote or one vote to their credit were discarded. The final descriptive ranked and ordered list of integrated elements for the status review of an engineering education system on the basis of the number of votes and their preference weightings were thus obtained. This reduced the total number of elements to 70 from the earlier 91. A list of such elements, along with their codes and keywords, is presented in Table 3.

Table 3: Integrated descriptive elements for the status review of an engineering education system.

SN	Band	Dimension	Element Code		Elements with Abbreviation or Keyword
1.	A	Organisational and Physical Aspects (OPA)	DE-45	a_{11}	Provision for encouraging students to learn through seminars, group activity, paper presentation, group discussion, etc (*learning through SGD*)
2.			DE-4	a_{12}	Emphasis on interdisciplinary education (*interdisciplinary education*)
3.			AE-12	a_{13}	Provision for financial and infrastructural support for placement activities (*F&I support for placement*)
4.			DE-10	a_{14}	Emphasis and provision for better library facilities equipped with modern and useful information systems to increase awareness and impart education of excellence (*better library facilities*)
5.			USEAAC-16	a_{15}	Evaluate engineering education system systematically (*evaluate engineering education*)
6.			DE-3	a_{16}	Emphasis on integrated education (*integrated education*)
7.			DE-52	a_{17}	Enable each student to build a strong character and high ethical standards (*build strong character*)
8.			DE-16	a_{18}	Provision for training programme and orientation courses to motivate faculty and supporting staff (*TRG-orientation programme*)
9.			DE-6	a_{19}	Provision for well-equipped laboratories (*well-equipped laboratories*)
10.			USEAAC-12	a_{1-10}	To develop innovative engineering career (*innovative engineering career*)
11.			AE-1	a_{1-11}	Provision for Distance Learning Programmes (*DLP*)
12			DE-41	a_{1-12}	Provision for student access to Small Scale Industries (SSI) (*access to SSI*)
13.			DE-42	a_{1-13}	Provision for Lateral Entry (LE) (*LE*)
14.			AE-16	a_{1-14}	Provision for addressing staff grievances (*welfare and grievance redressal*)
15.			AE-13	a_{1-15}	Provision for documentation facilities for Students and Faculty (S&F) (*S&F documentation facility*)
16.			DE-13	a_{1-16}	Provision for games and sports in order to develop discipline, honesty and a positive attitude towards life (*provision for games and sports*)
17.			DE-8	a_{1-17}	Provision to make students better suited to the increasingly techno-oriented environment (*suited to techno-oriented environment*)
18.			DE-44	a1-18	Provision for student's participation in the management and organisation of extra-curricular activities (*provision for extracurricular activities*)
19.			DE-12	a_{1-19}	Provision for the necessary basic infrastructure aimed at facilitating better educational environment like restrooms, pure drinking water facilities, common rooms and reception (*necessary basic infrastructure*)
20.			USEAAC-9	a_{1-20}	Offer broad-based education (*broad-based education*)
21.			AE-4	a_{1-21}	Provision for the empowerment of women (*empowerment of women*)
22.			DE-37	a_{1-22}	Provision for well-equipped workshops (*equipped workshops*)
23.			DE-9	a_{1-23}	Provision for computing facilities (*computing facilities*)
24.			DE-39	a_{1-24}	Provision for educational technology (*educational technology*)
25.			USEAAC-8	a_{1-25}	Recognise and facilitate the need for life-long learning (*life-long learning*)
26.			DE-40	a_{1-26}	Provision for student access to agricultural farms (*agriculture farm*)
27.			DE-2	a_{1-27}	Encourage intellectual activity (*intellectual activity*)
28.			DE-15	a_{1-28}	Provision for a Continuous Assessment System (CAS) (*CAS*)
29.			DE-34	a_{1-29}	Arrangement for vocational training (*vocational training*)
30.			AE-14	a_{1-30}	Level of faculty and supporting staff (*faculty & supporting staff*)
31.	B	Foundation Courses (FC)	DE-17	a_{21}	Emphasis on a foundation course to create general awareness (*GKC*)
32.			DE-18	a_{22}	Foundation course on culture and history (*CCE*)
33			DE-19	a_{23}	Foundation course on a comparative study of religion (*CSR*)
34.			DE-20	a_{24}	Foundation course on value systems (*CEV*)
35.			DE-21	a_{25}	Emphasis on agricultural operation (*AGOP*)
36.	C	Sociocultural Aspects (SCA)	DE-31	a_{31}	Creation of the spirit of fraternity among people (*brotherhood of man*)
37.			DE-32	a_{22}	Promotion of the establishment of a casteless and classless society (*society*)
38.			DE-47	a_{33}	The opportunity for each student to engage in drama, music and moral values, which can be emphasised through the organisation of such activities (*drama and music*)
39.			DE-49	a_{34}	Generation of consciousness for democratic values (*democratic values*)
40.			DE-22	a_{35}	Emphasis on rural development and rural engineering programmes (*RD/E*)
41.			DE-23	a_{36}	Emphasis on adult education programmes (*AEP*)
42.			DE-25	a_{37}	Emphasis on social service to make rural and urban students socially sensible and develop cooperative attitudes and a sense of service to others (*social service*)
43.	D	Spiritual, ethical and moral values (SEMV)	USEAAC-17	a_{41}	Refinement of the culture of professionals including faculty profile (in order to develop sincerity, good citizenship, trustworthiness, compassion and cooperative attitudes) (*professional culture*)
44.			DE-26	a_{42}	Inculcation in individuals of the spirit of truthfulness (*truthfulness*)
45.			DE-27	a_{43}	Cultivation of the spirit of humility (*humility*)

46.			DE-29	a_{44}	Cultivation of the spirit of selfless service and sacrifice (*sacrifice*)
47.			DE-33	a_{45}	Development of attitudes of tolerance and sense of national unity (*national unity*)
48.			USEAAC-5	a_{46}	Cultivation of an understanding of professional responsibility (*professional responsibility*)
49.	E	Personality Traits and Attributes (PTA)	USEAAC-7	a_{51}	Fostering of effective communication skills (*communicate effectively*)
50.			DE-28	a_{52}	Cultivation of the spirit of simple living (*simple living*)
51.			DE-51	a_{53}	Creation of an awareness of duty and obligations to society (*good citizenship*)
52.			DE-56	a_{54}	Development of temperance and courage (*temperance*)
53.			DE-57	a_{55}	Preparation of an individual for a calling suited to his/her aptitudes, skills and the needs of society (*aptitudes and skills*)
54.			DE-7	a_{56}	Development and promotion of a scientific focus in students (*scientific temper*)
55.	F	Professional and Academic Skills (PAS)	USEAAC-1	a_{61}	Development of the analytical ability to understand, apply and use techniques, skills and tools for engineering problems, and to verify(or validate) system behaviours in order to have at least one international centre of excellence (*analytical ability*)
56.			USEAAC-3	a_{62}	Development of the ability to synthesise problems (*synthesis*)
57.			USEAAC-4	a_{63}	Development of the ability to work in interdisciplinary groups (*interdisciplinary groups*)
58.			USEAAC-11	a_{64}	Knowledge of emerging technology that will significantly impact on society by providing opportunities for industrial experience (*emerging technology*)
59.			USEAAC-13	a_{65}	Development of a productive engineering career (*productive career*)
60.			DE-5	a_{66}	Emphasis on learning through experimentation, not just teaching, ie a project method of learning (*project method of learning*)
61.			DE-43	a_{67}	Work experience and field experience for graduating students (*work experience*)
62.			DE-55	a_{68}	Ensuring research enriched training (*research*)
63.	G	Employment Potential (EP)	USEAAC-14	a_{71}	Development of a satisfying career (*career*)
64.			AE-5	a_{72}	Career counselling (*CC*)
65.			AE-6	a_{73}	Regular professional competence testing (*PROCTS*)
66.			AE-7	a_{74}	Regular mock interviews (*MOCK*)
67.			AE-8	a_{75}	Status of campus interviews (*SCI*)
68.			AE-9	a_{76}	Alumni feedback network (*AFN*)
69.			AE-10	a_{77}	Level of placement (*LOP*)
70.			AE-11	a_{78}	Performance of the placement cell (*PPC*)

The domain experts, while scrutinising the elements during the process of editing, unanimously agreed that the element DE-54 (to bring about the physical, intellectual, emotional and ethical integration of an individual with the view to evolving a complete person who possesses the basic values of humanism, secularism and democracy, and who is capable of giving a fuller response to social and environmental challenges) should be considered as the mission objective of any educational system and should not be considered during an NGT exercise. However, they suggested that the phrase *well-evolved and wise professional* would be a better choice than a complete person, particularly in the case of engineering institutions.

In order to visually comprehend the pattern and status of an engineering education system, a visual scheme in the form of a *drishti-chakra* or status-visionary diagram has been conceptualised. This chakra is a circle that has two parts: lower and upper. The centre of the chakra is like the pupil of an eye, symbolically describing the objective of developing a *well evolved and wise professional* through the educational system under consideration. A well evolved and wise professional is a human being who has developed his/her physical, mental and spiritual faculties while nurturing moral and ethical values in an integrated manner so as to attain professionalism of a higher order with a superior level of consciousness. The lower part of the chakra is divided into seven bands as concentric half-circles, designated as A, B, C, D, E, F and G – corresponding to the respective dimensions given in the second column of Table 3. The outermost band is larger in nature, while the others are relatively subtler. The elements are numbered and coded, eg the element code $[a^{i}_{j}]$ implies the j^{th} element in the i^{th} band.

Each band has as many numbers of boxes (rectangles) as the element in that band. In order to complete the lower half of the chakra, the boxes are labelled in a band by the element code in an ascending order from east to west. The upper part of the chakra is a replica of the lower half and is symbolised as a question mark. It is where the pattern and the status value of an educational system under consideration would be visualised. The status scale is also provided at the south-west corner of the chakra, depicting the five status zones as dull, alarming, comfortable, cool and excellent, as follows:

- *Dull* signifies the scenario where efforts to improve the system may not be fruitful. It would be better if such a system is either completely overhauled or taken over by a new dynamic management or governmental agency, or may be allowed to close down;
- *Alarming* means sufficient efforts are needed for the evolution of a system to achieve the goal of a well-evolved and wise professional;
- *Comfortable* stands for the situation where more *oiling* in the management and system is needed to facilitate smoother running;
- *Cool* is the desirable status, but requires greater effort in order to transcend itself to higher human objectives;
- *Excellent* requires minor efforts to reach to the ultimate objectives.

Methodology for Status Evaluation

The chakra is not only helpful in giving a visual expression to the pattern of an engineering education system, but also aids in evaluating its present status. It is evident from the description of the elements in each band (dimension) of the drishti-chakra that they are highly subjective in nature and therefore probabilistic, or else simple numeric quantification will not be suited to such realistic but qualitative terms. This brings about fuzziness in the elements of drishti-chakra and requires its evaluation in the form of linguistic terminology and its consequential quantification with reference to its membership function. Hence, the domain experts and stakeholders could be asked to give each element in each band a status value that is nothing but a qualitative membership grade for a particular element, as per the perception of respondents with in a range of 0 to 1. In this range, a linguistic variable of *very poor* maps to 0 and *excellent* receives a value of 1. A value of 0.5 signifies *moderate* status. There can be infinite shades of perception between very poor to excellent, but to make it closer to a realistic limit, a value of up to two significant digits after the decimal point is allowed. Each respondent is expected to complete one chakra. Once this has been carried out, an aggregated drishtri-chakra is obtained by averaging out the status value of each element for all individuals because the average aggregation is valid in the fuzzy sets [30].

Finally, a System Status Value (SSV) is obtained from the aggregated drishti-chakra values a_{ij} as follows:

Step 1: Obtain the status value of each band (SVB) by the following formula:

$$(SVB)_i = (\sum_{j=1}^{ni} a'_{ij}) / ni \quad \text{for each i = 1………k} \quad (1)$$

Where:
ni is the number of elements in band i;
$a'_{ij} = (\sum a_{ij}) / N$,
and where:
N = the number of drashti-chakras;
a_{ij} = the Status Value (SV) a_{ij} of element j in band i;
a'_{ij} = the Aggregated SV of element j in band i.

Step 2: Assign weights w_i to each band on the basis of the preferred votes obtained with the help of another set of 10 domain experts (see Table 4).

Table 4: Preferred ranks and weights of dimensions (bands).

Band	Elements	Rank	Weights
A	OPA	II	2
B	SS	I	1
C	SCA	I	1
D	SEMV	III	3
E	PTA	VI	6
F	PAS	V	5
G	EP	IV	4

Step 3: Obtain the Overall Status Value (OSV) as follows:

$$(OSV) = [\sum_{i=1}^{k} (SVB)_i . w_i] / \sum_{i=1}^{k} w_i \quad (2)$$

Step 4: (SSV) = OSV$\pm$ tolerances

Step 5: Match the SSV with the status scale.

An Illustration

The application of the above scheme is accomplished by conducting a study of two engineering institutions, designated as A and B, in the city of Taj in Agra. This study has been conducted with the help of the domain experts. Each domain expert has been asked to complete the upper part of drishti-chakra as per his perception for the two institutions. This information has been analysed so as to give two aggregated drishti-chakras for institutions A and B. Finally, the System Status Values (SSVs) for the two institutions have been obtained with a tolerance of $\pm$ 2% of the opinions.

The result shows that the institution A lies in the comfortable zone, while the institution B lies in the alarming zone. A randomly chosen set of 15 domain experts, other than the experts in the previous one and excluding the authors, were also asked to give their opinions about the status of institutions A and B. These domain experts included employers from industries, academicians, officials from funding agencies and a few elites from society who had knowledge of the two institutions, but were not directly associated with them. More than 90% of the respondents were of the same opinion that had been evaluated earlier (see Table 5). This indicates that drishti-chakra can be utilised as a valid tool for evaluating the status of an engineering institution or system.

Synoptic Conclusion

It is evident from this brief review of technical/engineering education the world over that almost every nation, whether it be developing or developed, wants its education system to be able to advance and attain the competitive and economic relevance needed in order to sustain it in the near and far future. This can be achieved by integrating the concepts as discussed earlier to develop well-evolved and wise professionals.

Furthermore, before developing any meaningful system or process for the total quality evaluation of an engineering

Table 5: A comparative evaluation of the status values of institutions A and B.

	Institution A				Institution B			
Dimension	Opinions of I Set of Domain Expert	Opinions of II Set of Domain Expert	% Deviation in the Opinions of the Two Sets of Domain Experts	% Agreement	Opinions of I Set of Domain Expert	Opinions of II Set of Domain Expert	% Deviation in the Opinions of the Two Sets of Domain Experts	% Agreement
OPA	0.53	0.48	0.094	90.6	0.356	0.375	0.0506	94.9
FC	0.563	0.528	0.062	93.8	0.1375	0.125	0.0909	90.91
SCA	0.77	0.71	0.077	92.3	0.18	0.19	0.0526	94.74
SEMV	0.566	0.545	0.037	96.3	0.28	0.31	0.09677	90.32
PTA	0.658	0.593	0.098	90.2	0.27	0.292	0.0753	92.46
PAS	0.592	0.512	0.135	86.5	0.29	0.271	0.06551	93.45
EP	0.533	0.492	0.0769	92.31	0.187	0.198	0.055	94.44
OSV	0.596	0.565			0.213	0.268		
SSV	0.596±0.03	0.565±0.02			0.213±0.02	0.268±0.02		
	Comfortable Zone				*Alarming Zone*			

education system, a comprehension of its present status should be a prerequisite. The concept of drishtri-chakra is a step towards realising this requirement. Once this has been carried out, there automatically exists a need to develop a model through an integrated approach for developing standards and quality assurance in engineering education.

The development and realisation of such a model requires defining quality from the perspectives of the following:

- End users (eg students and parents);
- Providers (eg universities, colleges, technical institutes, government agencies and management).

This should be the starting point. A standard to monitor the fitness of education by providers to end users should be derived, keeping in mind the needs of industry, the market and society in order to advance peace and harmony besides evolving techno-economic development and effective employment. The authors are on the way towards developing such a model.

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