Chapter 20
Human Resources in Metrology for Skill India

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Abstract Human resource is fundamental to all strategic and coherent approaches in organizational management. To be a valued asset, human resource management assigns appropriate and skilled people working collectively towards a goal. Therefore, it becomes important for the organization to facilitate the necessary requirements such as infrastructure, education and skills. In this chapter the status of human resource in metrology in India has been reviewed and associated advantages and impediments were analysed. The growths of developed economies are also briefly discussed. The role of human resources in establishing a workforce in metrology, from Indian context, so as to enhance effectiveness of Quality infrastructure and make a socioeconomic impact, is also presented. Considering that human resource development requires both theoretical as well as practical knowledge imparted at laboratory or industry, the need to introduce the essentials of measurements from secondary level education to skill-development in tertiary university levels, as a part of the curriculum were highlighted. Besides, with rapid development in science and technology, it is also important that the industry personnel are updated with the current measurement science and technology by rigorous training. Analysis of gaps, challenges has been made and solutions are proposed for tackling the problem through a revised scheme of education system which includes personnel certification, skill developments and capability enhancement coupled with availability of career progression.
20.1 Introduction

Metrology is the underpinning science for the growth of the economy. It’s all pervading as it finds applications in all areas and affects all of us as consumers, manufacturers, or professionals. For example, the vehicles that touch the road have to undergo several hundreds of tests before being released to the market. These tests are starting from the phase of accepting materials to be used, manufacturing of components, assemble and post assembly testing. The smooth experience of driving and safety depends on hard work put into measurements for testing as much as the manufacturing. The same may be extended to all the products that we use. Professionals in different areas rely on measurements for the development and decision making, for example health professionals rely on the medical investigation’s reports; engineers depend on inspection reports to decide the acceptability as per their design specification and quality control; scientists use measurements for research, for modification or generalisation of theories.

Metrology or accurate measurement is not a new thing in our society; it existed since the beginning of the civilization. The thousands of years old Indian civilization has been known to practice measurements and have skills that could produce architectural wonders and texts describing solar systems and astrology. During the Bronze Age people started using measurements mainly for construction of dwelling units, town planning and exchange of goods. Indus valley civilisation (2600–1900 BCE) [1] (Harappa 3A, 3B, 3C) is well known to have measurement of length and mass [2]. Astronomical measurement and time measurement were also started during Indus valley civilisation and flourished during Vedic period. These measurements were necessitated initially for performance of rituals at correct time and for vedang jyotish. There is enough evidence from excavations of Mohan Jodaro, Harrappa, and DholaVira etc. that our ancestors had measurements skills that were quite advanced in those times. During British period, development of Indian industry was in low key, India was seen by British as source of raw materials and value addition to raw material development of Indian industry for processing and making finished goods was a low priority. Perhaps this was the reason that skill development also had a setback. During First World War, due to supply chain disruptions need to promote Indian industry was felt and testing of materials and products was realised. During that period efforts were made in consultations with Indian brain to create such infrastructure which resulted in creation of Government test house (National test house now) and later establishment of CSIR and NPL.
Worldwide, the need of accurate measurements and harmonisation of units was realized way back in nineteenth century. Harmonization of measurements across the globe was initiated by setting up the metre convention in 1875 as described in Chap. 1. The treaty and mutual recognition arrangements have resulted in realisation of a uniform scale of measurements in last century. In the middle of last century, India also adopted SI units and a uniform measurement scale had been realized and implemented across the nation. Nevertheless, the preponderant significance of precise and accurate measurements in scientific and engineering fields remains at challenge.

Presently India is in the era of liberalised economy and mass production. Mass production opens up an avenue on getting different parts made in bulk in different places and assembling to make final product. The compatibility and interchange ability of parts relies upon the precision measurements that are part of quality control exercise. As India is moving ahead and entering the brigade of developed nations, its export potential needs to be fostered by quality. Quality of local produce is essential for global competitiveness of Indian industry. Appropriate training to comply with the requirements of International mutual recognition arrangements and membership of relevant international organisations are essential for worldwide acceptability. These compliances of then industry produce are supported by Precision measurements, accreditation and standardisation. Rapid growth of India coupled with technology driven industrialisation underlines the need for skill development not only at lower level for employment but also for up gradation of employed workforce to make them capable to survive in the competitive and technologically evolving world. Emerging fields such as automated manufacturing, machine learning, nanotechnology, robotics, genetics, internet of things, quantum computing, energy resources and storage, materials science, biomedical applications etc., are few examples that poise the transformation and modernization at the workplaces. Human skills need to be developed and continuously upgraded to strike a balance with these advances.

Finding a balance between technology integration and human capital investments will be critical to enhancing productivity………….GCI report 2019 [3]

Further, industry 4.0 in India is expected to have dramatic changes in all human cantered technical, economic, administrative and environment professional fronts. In this view, the HR in metrology will become one of the essential objectives and functioning of national resource management.

Aswal’s model discussed in Chap. 1 has brought the metrology in forefront and an essential element for development of society and economic growth and thus requires development of metrology HR for inclusive national growth. The lack of training and skill courses in metrology is a problem that’s faced by organizations in developing nations. Developed nations usually have a well-placed metrology education programme to develop Human Resources for the quality infrastructure. As illustrated in Fig. 20.1 Metrology HR is linked to growth of various sectors like academia, industry, and legal metrology, standardisation, accreditation and framing of policies.

Human Resource is the key to success of any organisation, Society or economy perceiving people as asset. Human resources is the set of the people who make up
the workforce of an organization, business sector, industry, or economy [4]. From the very outset, HR’s involvement includes people employment and management, so as to achieve the goals, preserving the organizational and cultural values. Several intriguing challenges are encountered by organization in its endeavour towards having a socio-economic impact. One of such challenge is skill development planning. Skill India mission aims to provide market-relevant skills training to more than 40 crore young people in the country by the year 2022 [5]. The mission intends to create opportunities and space for the development of talents of Indian youth. Further, India has taken a challenge of self-reliance by launching Aatm Nirbhar Bharat mission. These are very much interlinked missions and require an effort into the HR part of the policies for meeting such an ambitious goal in timely manner. It’s imperative to analyse the status of HR in various areas, which will be important to meet this goal, analyse the needs and find the solutions that will make a desired impact. Broadly, HR in product quality infrastructure involves calibration technicians, calibration engineers and metrologists. With the advent of sophisticated instruments and methodologies, the workforce needs to be continuously updated. HR management includes knowledge and skills updating, establishing networks, fostering intellectual and emotional health and providing motivations. Thus, rather
than being a mere established practice at the workplace, HR relies upon policies and strategies enhancing employee capabilities and commitment.

To support the organization in achieving its objectives, it must be ensured that right people are at the right place executing their role at right time. This helps maintain a positive environment in the workflow of the organization. Hence, it becomes quite rudimentary to focus on skill development, optimization of project resources and time. People management and development when confined within the rules and goals of a particular organization, the role of the HR is more or less a constructive mapping of its resources and infrastructure to a socio-economic product. However, in the realms of metrology, HR role is complex as the workflow comprises of several independent but interlinked institutions as represented by the traceability pyramid described in Chap. 1. This chapter examines the national and international scenario of HR in metrology and highlights the need for development of metrology HR for Skill India. Significantly, it includes the highlights and contributions of CSIR-National Physical Laboratory, and also discusses the impediment and challenges to HR in Metrology and various proposals towards mitigating the measures. In view of the need for metrology education, it is recommended that metrology may be introduced in schools and explicit course subject in the university education. A consortium comprising of stakeholders from industry, government, educational institutions, accreditation and standardization bodies and national measurement institutes must be formed to make recommendations and nationwide implementation. Diploma and graduate courses in all disciplines of science, technology and social sciences, should have metrology practiced and the quality infrastructure inculcated. The existing technical institutes such as polytechnics also must be integrated with industries with emphasis on measurement science.

### 20.2 Demographic Dividend, Educational System and Employability

Demographic dividend is term used in urban industrial states; the term refers to shifts in a population’s age structure or increase in workforce and decrease in dependency ratio [6] resulting in the economic growth of the country. This dividend becomes available to a country due to decrease in mortality and fertility rates. As the country goes through a state with better health facility the mortality comes down. The reducing fertility rates result in more investment in child education and health. Participation of women also increases in formal employments. These factors result in a transition period where more and more workforce is available and dependency is lowered, meaning more working hands with lower number of mouths to feed. With passing of years, the development status improves but the lower fertility combined with increased average age results in phasing out of demographic dividend.

Thus various countries get a window of demographic dividend most developed nations have passed their demographic window while India is entering into this
window. Shifting age structure can result in demographic dividend window only through a very meticulous planning with investment in education and health system. Planning a policy for education such that, it meets the needs of industry leading to enhanced employability. In absence of such planning there can be negative spill overs like unemployment etc. rather than the dividend. Hence, there is an urgent need for the policymakers to align the developmental policies with this demographic shift.

20.2.1 India Demography

India is the second most populated country in the world with $\approx$1.3 billion counts [7]. The population have doubled during 1975–2010, and it is projected the country would be the most populous by 2024, surpassing China. With its population growth rate deduced as 1.13%, it is anticipated that by 2030 India, its population would become 1.5 billion, and 1.7 billion by 2050 [8]. Analysis also shows that 50% or more of its population age below 25 and more than 65% are of age below 35. This infers that the average age of an Indian will be 29 years (2020), making the country much younger to China (38 years), USA (38 years) Europe (43 years) and Japan (48 years) [9, 10]. Thus, a young human resource and a large working age population for coming 10–20 years, appear to be a promising dividend to make India a self-reliant and a fully developed state. Besides, due to increasing awareness in the society about the benefit of education to female, women who were earlier confined to home will join the work force in larger numbers. India’s dependency ratio is expected to fall from 0.7 (in 2010) to 0.4 by 2030. This further suggests that earning population would peak in future.

From the above, it is well understood that India has a demographic advantage. Study of various countries shows that high growth rates were achieved during the window of ‘demographic dividend’, defined by the United Nations Population Fund (UNFPA) as the growth potential that results from shifts in a population’s age structure [11–14]. Japan had its demographic-dividend phase from 1964 to 2004 and an analysis reveals that in five of these years, Japan’s growth rate was in double digits where the growth rate was above 8% in two years, and slightly below 6% in one.; growth rate of below 5% in only two of these 10 years [11]. China had reforms of 1972 and saw accelerated growth, the years of demographic dividend of China from 1994 helped sustain growth rate for a very long period. During 1978 to 1994 in an interval of 16 years (post-reform, pre-dividend), China saw eight years of double-digit growth. However, since 1994 China could not cross the 8% growth mark [11]. Analysis the demographic dividend data for two of the four Asian tiger economies also show similar patterns.

India’s shift in population structure by more than 60% of its citizen in working is a great advantage in terms of savings and investment rates. However, this demographic dividend poses several challenges [15]. With decreasing fertility rate, the present working class would move into dependent class in a matter of 20–30 years.
and the average age of the country’s population would go higher. This poses a “demo-
graphic echo” of aging dependent populace. Further, it also becomes important to
enhance scientific temper for a social change. Although at present, the demographies
look good statistically, it is less useful unless massive investments are made in health,
ariculture and education, and also spread widely to the corners of rural India. Hence,
policies need to be framed and/or modified to develop and educate the young minds,
nurture their skills, create employment opportunities and create an effective human
capital, thereby leading to an overall growth of the Nation. Besides, sector wise
discussion for HR policies and programs are also important and necessary. Govern-
ment of India is making efforts through its various ministries including ministries
of Science and Technology, human resource development, skill development, labour
and industry to meet the challenge (Fig. 20.2).

In view of the importance of metrology and the need to effectively use the demo-
graphic dividend for self-reliance of India, it is required to review the status of HR
in India, carry out in depth analysis and resolve the gaps through strategic inter-
ventions to convert HR into Human Capital. Even though Metrology is a key driver
for the growth of any Nation, the lack of training and skill courses in metrology

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**Period of Demographic Dividend in Large Countries**

![Graph showing the period of demographic dividend in large countries.](image)

**Fig. 20.2** India enters 37-year Demographic dividend window. The demographic dividend (DD) that is increased availability of workforce and decrease in dependency ratio presents unique opport-
unity for accelerated development. A comparison of DD windows shows among Asian countries
Japan has already passed it; Korea and China’s window will be passed in next decade. India has
this opportunity window till 2055. Planning on education in metrology is one of the factors that can
help to reap benefits [10]
is a problem that’s faced by organizations. HR development in metrology is necessitated by demand of quality and reliability of products. Broadly, HR in quality infrastructure involves calibration technicians, calibration engineers and metrologists. With the advent of sophisticated instruments and methodologies, the workforce needs to be continuously updated with the latest advancements in measurement science and technology. The need to meet the requirements put forwards by the dynamism of conformity assessment standards. For instance, as envisaged by World Economic Forum, Industry 4.0 is set to revolutionize trade and administration by means of digital technology. Emerging fields such as automated manufacturing, machine learning, nanotechnology, robotics, genetics, internet of things, quantum computing, energy resources and storage, materials science, biomedical applications etc., are few examples that poise the transformation and modernization at the workplaces.

As per world economic forum-Global Competitiveness report 2019, India has shown increase in innovation capability and there is need to improve talent base and to strengthen the skills to avoid the negative social spill over’s [3]. Further analysis reveals that India has scored low in GCI 2019 on finding skilled manpower. India reports good scores in R&D and innovation however; it has not so impressive overall rank. With industry 4.0 this problem will aggravate further and corrective measures are necessary. Emerging use of AI will require precision measurement and control in one package. Interdisciplinary courses with knowledge of ICT and measurements build into core syllabus are now inevitable when we are talking of self-reliant India. We need to create a system where ease of converting scientific innovation to a product is enabled by quality assurance or standardization is not limited to application of quality management systems like ISO 9000, It involves technical competence as well as competence of infrastructure resources as much as quality management standards.

Quality standards applicable in laboratories for example ISO IEC 17025: 2017 requires the technical competence and continual up gradation of skills of personnel, same is the case for with ISO 15189, ISO 17043, and ISO 17034 etc. implementing organizations, i.e., clinical Laboratories, PT Providers, reference material producers etc. Further on while doing calibration of an instrument or testing a product, there are standard norms written by standards bodies like BIS which need to be followed. Manufacturing and measuring these parts without imbibing the culture of metrology is like singing a song in an unknown language. One can of course sing such a song but will never know the meaning as in likely to miss the nuances.

20.2.2 Educational System

The modern system of education in India is due to Lord Macaulay in 1830. With English being adopted as the language of communication, the curriculum largely emphasized on science and mathematics. Subjects like Indian history, literature, philosophy was considered less significant. Further, teaching got confined mainly to
the classrooms. This change was a paradigm shift in the educational system, which earlier was based on the gurukul system. In the latter, the education was quite flexible, gurus trained their disciples according to the capability and talents of the student and concentrated upon an overall development; discussion and learning between student and teacher extended from the cosmos to the local political and social issues.

In 1952, several local boards of education, including the Board of High School and Intermediate Education was brought into one umbrella, and called as the Central Board of Secondary Education (CBSE). A second central scheme also exists in India, known as the Indian Certificate of Secondary Education (ICSE). In a matter of time, both CBSE and ICSE have spread not only among all Indian states, but also to countries beyond the international border. Universal and compulsory education for age group of 6-14 was adopted by the government of Republic of India. This was later strengthened with the National Policy on Education (1986) and the Programme of Action (1992), where it was envisaged that quality education may be delivered to all children across the country by twenty-first Century.

As per the constitution of India, school education was the responsibility of the respective state governments and had complete authority on policy making and its implementation. On the other hand, the role of the central government was mostly on setting standards in higher education. However, with the 1976 constitutional amendment, school education policies and programs were to be suggested at the national level, and the states find ways and means to implement it. A Central Advisory Board of Education (CABE), Ministry of Human Resource Development, which was set up in 1935, continue to lead the educational policies and programs of the country. Besides there is National Council for Educational Research and Training (NCERT) and its state counterpart called State Council for Educational Research and Training (SCERT), which plays an additional role in developing educational policies and programs. These units propose the curriculum, strategies, pedagogical schemes and evaluation methodologies.

Figure 20.3 shows the educational mainframe of India. The school system is categorized into four levels: lower primary (from age 6 to 10 years), upper primary (11 and 12 years), high school (13 to 15 years) and higher secondary schooling (17 and 18 years). The curriculum till high school remains more or less very similar across the country, except that the mode of communication. Several of the states adopt the communication to be in their respective regional language, which by itself is an additional subject to the national curriculum. Subject specialization begins at the higher secondary level with options in science, mathematical, social and information sciences. Generally, students were introduced to three languages; English, Hindi and their regional language and/or Sanskrit. Later on, in three language scheme, foreign languages like German, French, Spanish etc. has also been introduced as third language.

During the time of writing this chapter National education policy has been revised. NEP2020 [17] will have revised school years in stages called foundational, preparatory, middle and secondary, in 5 + 3 + 3 + 4 years of schooling, to be completed during the age 3 to 18 years. Degree courses will be four years. Technical education will be through diploma and degree course.
Unlike primary and secondary educations, which are largely controlled by the state, the tertiary level of education is largely set up on the standards laid by the University Grants Commission of India. As of 2020, India has more than 1000 universities including the central, state, and private. There are about 155 Institutes of national importance which include IITs, IIMs, AIIMS, NITs, IIITs and IISERs, and are empowered to examine their own degrees, up to Ph.D. level. In all fronts, the tertiary level of education lies on science, technology and social sciences. Apart from these, there are also several distance learning and open education programs which are monitored by the Distance Education Council. Indira Gandhi National Open University (IGNOU) is the largest Open University in the world by regard to the number of students.

There have been many reforms in the education policies however still lot of scope of improvement exists in the education system. To address the prevailing gaps Indian higher education needs radical reforms so that quality of education as well as world rankings of India Universities can be improved. Efforts for improvements must be primarily on improving the vocational, technical and doctoral education. A strong public-private coordination and professionalization of the courses must be considered at highest priority. In fact, in the early 1990’s India did cash on the rising demand in the IT sector and engineering education. However, updating of the IT segments to machine learning, robotics, algorithm developments, artificial intelligence, digitization technology are yet to be implemented. With enormous diversity in population, concerted efforts should also be broadened to include arts and sports education.

The sixth report on All India Survey on Higher Education (AISHE) 2015-2016 finds that the total enrolment in higher education is approximately 34.6 million with 18.6 million boys and 16 million girls, with girls constituting 46.2% of the total enrolment. There is also a surge in the number of foreign students enrolled in higher education in India. The survey finds that the highest share of foreign students come from the neighbouring countries: Nepal (21%), Afghanistan (10%), Bhutan (6%),
and from Nigeria and Sudan (5%) each. However, on the contrary, it is also found that there is an increasing trend showing that more Indian students opt for education abroad after their post-graduation from Indian universities. As per the statistics of “The U.S. Council of Graduate Schools” Indian post-graduate students admissions went up by 25% in 2013-14 from its previous year. To limit the brain drain from the country, Dr A. P. J. Abdul Kalam once quoted “In decades time, India will need 300 to 500 million employable skilled youth and there’s a need to completely change the university education syllabus and secondary school education syllabus”.

20.2.3 Metrology In Curriculum

To a large extent, quantitative measurements are mathematical in nature, assigning numbers to a physical observable. However, rather than being mere numbers, the measured value actually is a conglomeration of the theory, methods and techniques used to understand the concept (property being measured). A priori, metrology being a science and practice of measurement has several desired factors in anticipation. CSIR-NPL has been advocating on providing exposure to SI units and metrology right from schools. In Indian educational curriculum, the first fully devoted chapter to measurements is in the class XI physics textbook titled “Units and measurement”. Out of seven fundamental physical units, three of them (length, mass and time) are detailed at this level. However, the recent change in the definition of mass has not been modified in the textbooks, despite CSIR-NPL making recommendations for it. It is therefore proposed that the chapter may be elaborated to include all the seven SI base units and their importance so that students feel motivated at a very young age. Also, the basic definitions as laid by the VIM [18] document of metrology can be well introduced at this level. Statistics, which is an essential tool in measurement science, is included in the mathematical books at the higher secondary levels. Grouping of data into frequency plots, pie-diagrams, use of inferential statistics etc. are known to students by the end of their school career. Nevertheless, there still remains a wider scope to emphasize on the statistical tools to envisage the meaning of the basic laboratory experiments pursued in the school laboratories. Several institutes and universities of India have now implemented metrology as a dedicated credit course at the Bachelor’s level. The syllabus includes measurement glossary of terms such as accuracy, precision, resolution, traceability, uncertainty, tolerance and others. The courses also cover information on the various hand-held measuring devices, automated measuring systems, significance of statistical processes relative to measurement theory, understanding of the relationship between quality and metrology, working knowledge of various standards used in everyday practice in the field of electrical, mechanical and electro-mechanical equipment. The contents of the course is expected to benefit students to pursue a career as Laboratory technicians involved with testing and/or measurement, Six Sigma (6 σ) practitioners, Quality control specialists, for engineers and technicians involved with manufacturing facilities and developing critical-to-quality specifications on components and assemblies,
etc. Apart from traditional degree courses Indian system offers several Vocational trainings in country which includes vocational secondary or vocational course after 12th. Vocational learning involves essentially hands-on training through which one improves capabilities and experience which is straight way related to occupation in future. It assists scholars to be skilled and thereby, attain better employment openings. The traditional courses offered are sometimes not able to fetch employment. Among the disciplines computers are most sought after course. A package of metrology with electrical/mechanical area can be designed to improve the skills imparted [19].

20.2.4 Employability fall Causes and Concerns

The fall of employability is a long-standing problem in the Indian economy. Employability of university graduates is decreasing, as shown in Table 20.1, it was noted in 2017 that 60% of engineering graduates remain unemployed, while a 2013 study found that 47% of them were unemployed in any skilled occupation. India’s overall youth unemployment rate, meanwhile, has remained stuck above 20% in the past few years.

The fall in the employability, in particular concerning that of Industrial Training Institutes (ITI), Industrial Training Centres (ITC) and polytechnic must be urgently considered on priority and necessary steps must be taken to improve the skill sets of students who pass-outs from these segments. In general, the ITI, ITC and polytechnic students constitutes a large portion of the MSMEs. Education and professional degrees in present-day India need drastic restructurings so as to improve employment prospects plausible solution is to integrate the final course curriculum of these ITIs and ITCs with national and state level laboratories that have advanced and sophisticated instruments and can teach nuances of precision measurements. With multi-disciplinary applications in basic and applied sciences, engineering

| Skill      | 2014 (%) | 2015 (%) | 2016 (%) | 2017 (%) | 2018 (%) | 2019 (%) |
|------------|----------|----------|----------|----------|----------|----------|
| B.E/B.Tech | 51.74    | 54       | 52.58    | 50.69    | 51.52    | 57.09    |
| MBA        | 41.02    | 43.99    | 44.56    | 42.28    | 39.4     | 36.44    |
| B.Arts     | 19.1     | 29.82    | 27.11    | 35.66    | 37.39    | 29.3     |
| B.Com      | 26.99    | 26.45    | 20.58    | 37.98    | 33.93    | 30.06    |
| B.Sc       | 41.66    | 38.41    | 35.24    | 31.76    | 33.62    | 47.37    |
| MCA        | 43.62    | 45       | 39.81    | 31.36    | 43.85    | 43.19    |
| ITI        | 46.92    | 44       | 40.9     | 42.22    | 29.46    | NA       |
| Polytechnic| 11.53    | 10.14    | 15.89    | 25.77    | 32.67    | 18.05    |
| B.Pharma   | 54.65    | 56       | 40.62    | 42.3     | 47.78    | 36.29    |

*Table source* India skill report, 2019 [20]
and technology, metrology require more emphasis as a full-fledged curriculum. The process of measurement, analysis and testing to secure the traceability are very complex and thus require more competent and rigorous specialization. Hence, India may establish a centre or a college dedicated for metrology. In this perspective, CSIR NPL has already started a diploma programme on “Precision Measurement and Quality Control (PMQC)” which is running under the aegis of AcSIR, India. The details of this course are given in Sect. 20.5 nevertheless; NPL’s intention is to further expand the course, as it has been proven to have 85 to 100% job placements to the students who qualify the course. The proposed segments in future would include, machine learning, big-data analytics, automation, certified reference material metrology in chemistry and others.

According to Pravin Sinha [21] the three adopted classification of the Indian labour force are, (i) Rural sector (includes farm labour), (ii) Urban formal sector (includes factory and service industry) and, (iii) Urban informal sector (self-employment and contract/casual wage workers). The rural and informal sectors in Indian market accounted for more than 90% of the employment in 2011. However, at the time of survey, these jobs are not considered by the existing Indian labour laws. On the other hand, World Bank report of 2010 finds that the low-paying and relatively unproductive jobs are dominant in the informal sector jobs [22]. Metrology plays a great role in urban formal sector. There are more than four lakh testing and calibration laboratories. According to association of Indian laboratories, these laboratories face lack of attention by Government. These laboratories provide essential services; however, their pain was that during COVID 19 situation they faced a problem of neither being recognised under industry norms nor under essential services. This is an example that need of Human resource for such sector is neglected. Their need is the manpower trained in metrology and related quality management aspects. Aswal’s model takes a note of this situation when it talks of QI and four helices together.

20.3 Metrology Training in India and Contribution of NPL India

Regardless of the stream of education, training and knowledge dissemination is integral part of growth and development of any society. In general, school and colleges keep many frontline activities along with traditional course structure in their course curriculum. However, one of the disconcerting problems associated with education in India is that metrology has not received its due recognition in most of the course designs neither in schools nor in higher education. In recent past few academic institutes in India have begun to comprehend the significance of metrology and have included basic metrology in their curriculum; however, it is not sufficient to cater the country’s requirement. Measurement is an integral part of our daily life as well as many applications like research, automobile, space, pharmaceuticals, satellite
etc. Off late, it has been accepted that metrology provides an essential basis for all the engineering and science disciplines along with related areas such as medicine and the law. For example, if the person measuring or sampling the blood for measurement of blood sugar is not trained, the results may not be true or it can be false positive meaning that it falsely exceeds its true value, the specialist recommends medications, or if the measured blood sugar is falsely below its true value, medicament will not be scheduled. In such cases either the patient will consume unneeded drugs and waste money or will face hypoglycaemia leading to risk of injury/death. This scenario is not limited to developing countries only, even in developed countries there are example of measurement errors. One such well-known case of measurement error is NASA’s Mars Orbiter where NASA lost a whopping $125 million [23–25] because of software not taking care of unit conversion. English units of measurement were used by Lockheed Martin Engineering Team while the NASA team utilized metric system for a key spacecraft operation, according to an examination finding. Due to this conversion factor not being considered, the propulsion system of the spacecraft was suspected to be overheated which might have triggered an alarm to disable it. That probably stopped the engine from completing its burn. This might have resulted in dipping of Climate Orbiter deeply into the atmosphere [23–25]. That probably stopped the engine from completing its burn, so Climate Orbiter likely ploughed through the atmosphere. This could have been perhaps stopped if software developers were aware of the importance of units.

Further, metrology plays an important role in lowering the technical barriers to trade through the National quality infrastructures comprising of a National Measurement institute, a standard writing body, a body for enforcement of law and a network of accredited testing, calibration and inspection [26] for any Country. In the era of Global trade various economies of the world depend on each other for raw material as well as finished goods. Hence raising quality standards and infrastructure in these trade connected countries becomes responsibility of all. Countries are classified as developed, developing and least developed countries depending on their development index [3, 27, 28]. Despite the importance of metrology and it being the growth engines, the development of Human resource in metrology area that has been talked about by many researchers internationally [19, 29–37] as not being given its due importance. In most developing countries there is no course of specialisation of metrology in formal education. Metrologists acquire knowledge of this trade on the job and by way of short-term courses. As this realisation has come in some countries like Brazil, Lithuania, and Nigeria, steps have been taken for development of HR in these areas [19, 33, 38, 39]. The state of development in country is related to its technology adaption and relates to status of metrology. Developed nations owe, their transformation from developing to developed state, to development of metrology temperament. The developed nations have taken effort to explain even the most complex metrology achievements and the exciting science behind it in simple ways to engage attention of school kids and general public [40]. US and UK have large number of metrology courses. Their ways of implementation may be different but effort on metrology education is seen [33]. The need for development of metrology education is usually recognised by NMIs and other elements of QI
[26], however it usually becomes difficult to convince Governments and stake holder of education system. Thus, these elements resort to international collaboration and training on job. International collaboration in development of HR in metrology has been the way out for global consumerism for a long time. Developed countries help the developing and least developed ones to realise the importance of human resource development in metrology and QI. This helps to maintain the conformity assessment echo system. Not only measurement, the environment/culture also play a crucial role in the measurement or testing results. Development of scientific temperament in society is also as essential as metrology temper. For example, India trades with several countries for more than 200 spices and spice products in whole, powdered, blended and mixed forms which include pepper, cardamom, spice oil etc. [41]. In the last few years, imports of Indian spices have increased many folds in value, however, due to contamination and failure of exporters in maintaining the quality standards of the spices, FSSAI is rejecting lot of imported spices and other spice products. An acquaintance once narrated an anecdote about spices from Indian farmers being rejected due to animal excreta detected in the spice sample. The experts investigated the cause and visited the site and released the technical review of their findings. It was found that the farmers were spreading the spices on the floor for sun drying. As per the prevalent tradition in India an emulsion of cow dung in water is made and a layer of it is applied over the entire flooring. The animal excreta reported in samples was actually traces of cow dung coming from the floor on which spices were sun dried. Thus, the problem was solved with necessary training provided to farmers with an instruction to use appropriate sheets over the floor for sun drying of the spices. Some examples for rejection criterion are; the clove sample does not conform the parameter for Headless clove and Extraneous matter as per standards laid down, Cassia sample fails for the parameter of moisture, coriander samples failed for split fruit and discoloured fruit criterion, Chilli and turmeric exports from the Guntur belt to the Western countries have been rejected due to the presence of excess pesticide residue and toxins in them and their related products etc. [42]. Similar examples exist in various fields, value addition of raw material can be done by grading through testing and further value addition happens by process or manufacturing those results in final products. Compliance to national and international standards is required in such value chain. Small interventions of building skills in quality handling and awareness about testing norms can solve the problems described in Fig. 20.4.

Developed countries have a well structure and experienced quality infrastructure and have trained personnel for the measurements. However, with advancement and the new players in market, they also face this impediment of HR in metrology and short courses become the way of re skilling and up skilling. It has been reported that for many years the formal education in metrology was not available in universities and US military trained the personnel for precision measurement [35, 40]. There are short term courses offered by NIST the NMI of US, its accreditation bodies and few other schools covering various parameters like, mass, temperature, length etc. [40]. In United Kingdom there are metrology courses available from NPL UK in both modes class room courses as well as e-learning courses. NPL UK also cooperates with others to run metrology courses by providing the course material developed
Fig. 20.4 HR competency in measurement and testing is needed for value chain that is value addition by grading, processing, production and delivering quality products

by its learned and experienced metrologists [43, 44]. Educational institutions of US, France, Australia, Germany etc. offer various metrology programs or classes in developed countries [33, 45]. Some of these courses are available internationally for training of metrologists [33]. The data reveals that very few endeavours have been made to introduce specialisation in metrology in higher schools of learning.

Need for this enabling knowledge arises at various levels, e.g. for industrial metrology availability of personnel at shop floor levels to do measurement during production. Similarly, inspectors, calibration or testing technicians, technical managers and quality managers is inevitable. In MSME sectors, one person may play many of these roles. The lack of availability of work force in metrology skills, forces the organisations to take up the available manpower and train them on the job by way of consultancies or training courses available, thereby affecting the productivity of these personnel in initial years. In case of Brazil, they handled the situation differently and set up a master’s course of one-year duration [32, 38] which, has been implement with due planning., Brazilian National Institute of Metrology (INMETRO)cooperated with agency for coordination of programs of master's degree and a university to train 60 people in two groups in 1975-76, which were absorbed at NMI and further trained continually at PTB Germany. Brazilian Government created Human resource for metrology programme in 1995. During 1998 to 2002 after detailed mapping of metrology need the first regular course was launched and programme consolidated in 2006. The program is reported to be a great success and of benefit to NMI, accredited labs, R&D and society. Many other studies and review show that the countries have made recommendations and taken steps to mitigate the weakness of metrology education.

As discussed in Chap. 1, CSIR-National Physical Laboratory, India, is National Metrology Institute of India. With the advancement of science and technology and emergence of mass production, need for precise measurement came into the force.
Further, for the development of new materials and new technology accurate measurements are also required. The human resource for NPL was selected with utmost care and interest by the great visionaries like Dr K. S. Krishnan, the first Director, NPL and Dr S. S. Bhatnagar DG, CSIR. Both these leaders are well known for their farsightedness and vision that helped in shaping India’s S&T as well as metrology infrastructure. In first two decade of NPL, its service to Industry included advice, testing and specialised services \cite{46, 47}. The facilities at NPL India were established for metrology which in initial years was to support legal metrology and trade. NPL’s scientist and officers were par excellence and were groomed by learned scientists who were at the helm of the affairs and involved in policy making and recommending on standardization. These scientists were given international exposures to present their work to learn newly developing methods. While on job, they were trained in areas of emerging methods of metrology and materials in cooperation with other NMIs and universities of leading Nations. Thus, the human resource of NPL was looked after and nurtured with knowledge to meet the ever-increasing demand for modernisation and Industrialisation. These people of NPL trained young minds by way of having them as guest worker. NPL was most obvious choice for young guest workers from different institutions of India, owing to its state of the art facilities, and availability of the brilliant faculty. Later on, this developed into Ph.D. programmes, internship, and training for graduate and post graduate students. Ph.D. Students worked at NPL and registered at various universities.

Around late eighties vocational training programmes of two years duration was organised to provide training in various trades, including three months training in species plant at NPL.

20.3.1 **Industries, Testing and Calibration Laboratories**

Measurement provides quantitative knowledge about the process, its control, adjustments or modifications. The need for precise measurements has turned out to be essential since the commencement of Industrial revolution. With the advancement in the technology, the requirement of industries keeps changing resulting in a continuous process of learning and training with the changing needs of the industry. Worker from an industry requires theoretical as well as hands on training which will be beneficial for their own research problems. It will be an added advantage if the environment of standard laboratory is provided for such learning. This kind of training and education improves the quality of personnel and workers and promote quality control in industry. In India there are four lac testing laboratories out of which > 5600 are accredited laboratories \cite{26}.

A survey was conducted in Industries, testing and calibration Laboratories, to find out their requirement towards type of training courses they need and preference of organization for such training. Following graphs shows the current external training requirement trend and its type (Fig. 20.5).
Further, Metrology education and training of personnel for repair and maintenance services of scientific and technical equipment should also be planned for the industries so as to make them self-reliant. However, the foremost barrier is to find appropriate education and training programs which is designed based on the needs of industry/laboratory staff who undertake measurement, calibration, testing or verification. By and large many industries and laboratories are ignorant or do not pay attention about the required set of knowledge or skill to be possessed by a worker in order to be competent for the assigned job. Mostly managers or human resource (HR) persons play a very crucial role in recruiting new worker or assigning job to the existing employees. Students of universities, technical colleges and other institutions of higher learning are the potential managers and professional experts. They are responsible for implementing the quality system in the companies. Mostly the management policies are inclined towards the contentment of HR people instead of the operating process requirements like measuring parameters, tolerances, measurement uncertainty, specifications, etc. Metrology areas are comparatively unfamiliar to several HR specialists as compared to traditional occupations like chemists, physicists, biologists, or the engineering professions. Therefore, special training with overall understanding of Metrology and Quality system is mandatory for managerial positions too. Due to lack of such training, they are not able to do justice with the worker and company. Management team usually has persons with MBA, they choose what they consider the finest training in metrology course for their people. However, this approach does not cater the actual requirements of training of the people carrying out measurement jobs in the institution (Fig. 20.6).

In the absence of structured courses, requirements of the companies in particular of MSME’s are fulfilled by hiring workers and providing them on job training. In general turnover of MSME’s are quite low, on job trainings are quite taxing on time and money for such companies as it is utilizing hours of pre-existing trained manpower and infrastructure of the company, however not much output is attained from the newly hired person. In view of this, these jobs are underpaid and not very lucrative to the employee/worker. As a result, staff retention in MSME’s is a critical
Fig. 20.6 NABL accredited organizations need training in metrology and quality systems. Survey reveals that many freelance and private players are providing training and this indicates necessity of setting standards for such training.

issue. After the value addition in their profile, workers tend to move to Big Houses (Large scale Industry) where they are offered handsome pay package along with additional benefits. The MSME’s suffers a lot in this process as they have to train again a new manpower with no certainty to retain it. It is a vicious cycle for the small-scale industry sector. Further, there are also some cases, when big houses go for accreditation, they are in desperate need of quality system and metrology trained manpower. They lure trained people from MSME’s by giving them higher pay packages. However, as soon as the accreditation process is completed the hired manpower becomes redundant for them and thus is fired.

There can be a situation when, only few comprehend the techniques and structures that are essential to the work in that area, and they go on leave or quit the job. To overcome problems arising from such situations, where only the operational knowledge has to be apprehended prior to the employee’s exit, otherwise it would lead to a knowledge void. Most of the time, organizations do not save, record or register the knowledge developed by their people performing measurement functions. The knowledge curve has to be developed again whenever altered or fresh worker embrace the job. Thus, knowledge management is an area which needs to be considered and nurtured in industrial culture. Use of information technology for knowledge management needs to be enhanced. Identification of skill sectors on metrology, statistics, quality managements and accreditation standards, use of ICT in knowledge management need to be taken on priority for skilling and up skilling.

Metrology has been understated and its prominence in the progress of a company/lab has never been understood specifically. It is considered less than the crucial or basic processes of most companies. The significance of metrology is understood in an industry/company typically, (i) when there is a serious problem in production/process which leads to major negative economic impact on the concerned entity which otherwise could have been avoided if good measurements had been warranted.
(ii) When there is a requirement from the client to fulfil the traceability norms and conformance criteria.

Since its Inception, CSIR-NPL is playing significant role in contributing towards the metrological needs of the country. CSIR-NPL is providing calibration, testing, consultancy and education and training to industries, companies, laboratories, SAARC countries and most importantly young minds who are going to be nation builder in future. The role of NPL India in Metrology training will be dealt in detail in the next section. Apart from CSIR-NPL, many more organizations in India are playing important role in disseminating knowledge and providing training in Metrology, quality system and infrastructure as shown in Table 20.2 (Fig. 20.7).

20.3.2 Endeavours of CSIR NPL for Skill Training

From early years CSIR-NPL has been advising Industry towards development of quality infrastructure, precise measurement techniques etc. Gradually, it was felt that imparting training in more formal manner and organizing awareness program is essential for societal benefit and acceptance of MADE IN INDIA products at international forum. In view of this NPL India designed parameter wise classroom/practical courses as per the requirements of the customers from laboratories/industries which continue throughout the year. With the liberalisation and setting up of accreditation infra-structure the new calibration and testing laboratories started coming up and NPL’s role in shaping the human resource became more crucial in nineties and early 2000. During this period the new training institute and laboratories depended on human capital of NPL till they had sufficient training of their trainers. These courses were organised in cooperation with MSI, NABL etc. at NPL campus mostly. NABL together with NPL faculty conducted region wise training programmes to help harmonisation practice in India. NPL’s expertise was most sought after in those days.

With changing needs, the courses have also evolved from basic training to specialised training. The recent policies of Government of India have created vast opportunities in India in various sectors. These sectors need skilled manpower. NPL’s focus on human resource developments in line with Sustainable Development Goals and Government of India Missions of Skill Development and Make in India, for supporting industries, accreditation bodies, regulators, S&T and other stakeholders. In view of increasing global competition many industries are going for ISO certification, using precision measurements and implementing quality control measures. The industries in India, especially MSME sector need support in terms of up skilling of human resource. NPL, India, being the NMI of India, is uniquely positioned to cater the needs of training in these areas.

Presently NPL is committed to capacity development for strengthening the QI of India to support economic growth. It has variety of programmes designed for different stake holders
| Organization                                                                 | Courses                                                                 |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------|
| National Physical Laboratory India                                         | One-year PG Diploma in precision measurements and quality control       |
| National Physical Laboratory India                                         | Short Courses in mechanical, Optical, thermal, material, environment, Electrical, time and biomedical metrology |
| National Physical Laboratory India                                         | 2–6 months training to UG and PG students                               |
| Institute for Design of Electrical Measuring Instruments (IDEMI) IDEMI, Mumbai | Dimensional Metrology                                                   |
| Fluid Control Research Institute (FCRI), Kerala                            | Metrology, Pressure, Thermal and Electro technical Measurement and Calibration |
| Central Manufacturing Technology Institute (CMTI), Bangalore                | Metrology and Calibration                                               |
| Nettur Technical Training Foundation (NTTF) NTTF, Kerala                    | Certificate Program in Inspection and Metrology                          |
| Swayam and National Programme on Technology Enhanced Learning (NPTEL)      | Engineering Metrology                                                   |
| Electronic Test and Development Centre (ETDC), (Bangalore, Chennai, Hyderabad, Pune, Goa, Jaipur, Mohali, Solan, Guwahati And Agartala) | Short Courses in Mostly Electrical and Electronics Measurements, Also Mechanical and Other Measurements |
| Electronics Regional Test Laboratory (ERTL) (N) Delhi                       | Short Courses                                                           |
| (E) Kolkata                                                                  | Testing and Calibration                                                 |
| (W) Mumbai                                                                  |                                                                         |
| (S) Thiruvananthapuram                                                      |                                                                         |
| Organization                                                                 | Courses                                                                 |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Centre for Electronics Test Engineering, (CETE) Pune, Hyderabad, Bangalore, Kolkata, Noida, Kolkata, Delhi | Testing and Calibration  
Reliability Engineering Programs                                                   |
| Indian Institute of Quality Management                                      | Evaluation of Measurement Uncertainty Testing, Calibration, Quality Management etc. |
| Standardisation, Test, and Quality Control (STQC) IT Centres at Delhi, Hyderabad, Kolkata, Chennai, Bangalore, Pune, Jaipur, Mohali and Guwahati | Software Quality Engineering                                                 |
| Centre for Reliability (CFR), Chennai                                       | Training and Certification of Industrial Employees in The Field of Reliability Engineering |
| BIS Training Institute                                                       | Quality Systems and Standardisation                                        |
| National Institute of training in standardisation NITS, Noida                |                                                                           |
| Various Boards Like Spice Board                                              | Training in standards and testing                                          |
| ARAI, Pune                                                                  | Automotive Testing and Measurements                                       |
| National Test House                                                         | Training in calibration testing                                            |
| Confederation of Indian Industry CII                                        | Quality system certification, Standards, accreditation basic metrology    |
20.3.2.1 Short Term Training for Industries, and Other Sectors

Training programmes consist of theory lectures on various scientific and technical aspects followed by practical demonstration and hands-on training on the related instruments/apparatus/machines. These programs cover Physico-Mechanical Metrology, Electrical, Time and Frequency, Environment and Material’s Metrology, radio and environment metrology as shown in Fig. 20.8. These programs can be tailor made according to the exceptional request of the customer or a particular sector. Examples are, a course designed to suit the needs of Air India, or Department of Legal Metrology etc. A glimpse of past decade of training programmes tells that Mass, length, pressure and quality are in great demand as shown in Fig. 20.9. Training of students and faculty from S&T institutes on Material characterisation, Nano science, Photovoltaic was carried out on demand basis. The reason for this may be attributed to the lack of facilities at private institutes of higher learning. Students want to have exposure to these techniques to increase employability (Fig. 20.9).

20.3.2.2 One-Year Full Time PG Diploma Course in Precision Measurement and Quality Control

The recent policies of Government of India have created vast opportunities in India in various sectors. These sectors need skilled manpower. Government of India has launched a “Skill India” programme for supporting industries and other stakeholders. In view of increasing global competition many industries are going for ISO certification, using precision measurements and implementing quality control measures. The industries in India, especially MSME sector need support in terms of providing specific trained manpower. Lack of the trained manpower is not only a major constraint for industries and manufacturing/production sector but also for
CSIR NPL India’s short-term training programmes are organised for various measurement parameters. Length, mass, force, quality system, temperature, electrical and electronics measurements are most sought after by industry for training. Pressure, environmental, materials and photovoltaic and Biomedical have got demand recently.
calibration and testing laboratories. NPL, India, being the NMI of India, is uniquely positioned to cater the needs of training in these areas of industrial importance.

Today due to increasing demand of high quality products as well as their global acceptability, Industries and production units are standardizing their products with ISO/IEC conformity assessments following national and international specifications for the product and set up or liaisons with NPL India/accredited Testing and calibration laboratories complying to International Standard; ISO/IEC 17025 (General Requirements for the Competence of Testing and Calibration Laboratories) for traceability needs. Laboratories in medical field conform to ISO 15189: 2012 (Medical laboratories - Requirements for quality and competence). These laboratories seek recognition for their proficiency by participating proficiency testing programmes run as per ISO/IEC 17043: 2010 (Conformity assessment - General requirements for Proficiency testing) and use reference materials from ISO Guide 34: 2009 (General requirements for the competence of reference material producers) complying manufacturers or Bhartiya Nirdeshak Dravya (Trademark of NPL India). These Organisations need human capital enabled with knowledge and skill for measurements and quality control.

Such skilled workforce is a catalyst to enhance productivity, minimise losses and to overcome technical trade barriers and thus facilitates global competence to cater international needs and helps international branding of local produce.

During interactions with Industry, it has emerged that knowledge of precision measurements and quality control is generally available with few personnel like managers or senior engineers who learnt it on the job over the years. However, the people at shop floor level who carry out day to day production and measurement do not have adequate knowledge of the subject and carry out work as per the instructions
given. In today’s competitive world, in order to maintain the quality of products and reduce the rejection ratio, it is essentially required that the staff actually working at shop floor level must have training and exposure.

NPL, India, being NMI of the country, therefore, came forward to create trained manpower in areas of precision measurements and quality control to accelerate the growth of industry. CSIR, encouraged by Skill India call from honourable Prime minister, Shri Narendra Modi, launched its integrated skill development programme in 2017. Based on CSIR-NPL’s strength and expertise in accurate and precise measurements, a well-designed full time one-year certificate course was initiated on precision measurement and control. This course was aimed to meet the needs of National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited testing and calibration laboratories, legal metrology institutes and improvement in efficiency of manpower and industries. Two batches of this course had a good placement. In view of success of this course, it was upgraded to be run at CSIR NPL as ‘Post Graduate Diploma in Precision Measurement and Quality Control’ under the aegis of Academy of Scientific and Innovative Research (AcSIR) which is an Institute of National Importance under Government of India with Ministry of Human Resource Development (MHRD ID No. U-0713) [62].

**Main Features of Course** [59]

(a) **Personal Growth** by meticulously designed course modules with a blend of classroom lectures, discussion, tutorials and practical related to measurements, testing and calibrations.
(b) **Transformation** by industrial oriented experimental learning and exposure through hands-on experience in industrial internship.
(c) **Academic Support** to students, world-class infrastructure, free access to SCI journals in library, seminars and lectures,
(d) **Multidisciplinary Skill Development**, faculty with extensive experience in precision measurements.

**Placement Opportunities:** On successful completion, young minds trained in this discipline have a unique advantage of wide exposure and hands-on training on best equipment/standards for measurements. These professionals have good placement opportunities in quality control(QC), accredited laboratories, manufacturing and production industries, Micro, Small and Medium Enterprises (MSME) and many other related industries, Government, public and private sector. The manpower trained by NPL, India will be attractive to these sectors. They will not only be the most suited candidates for Government or private industries, manufacturing sectors but would also be an asset to Government run legal entities, e.g. National Accreditation Board for Testing and Calibration Laboratories (NABL), Quality control sections, Testing and Calibration Laboratories from Private/public/Government sector, Legal Metrology Department, Standardisation, Testing and Quality Certification (STQC), Quality Council of India (QCI), etc. The demand of skilled manpower for precision measurements in manufacturing sector and quality sectors identified above will be increasing day by day. This way the trained manpower in precision measurements through this certification course would have ample job opportunity.
20.3.2.3 Metrology Skills for Accreditation, Standardization and Legal Metrology

CSIR-NPL has made a huge contribution in creating Human resource for establishment of accreditation infrastructure that exists for testing and calibration laboratories in India today. The visionary MGK Menon called for making an effort on coordination of testing and calibration facilities in India. In 1981 [58], Department of Science and Technology set up National Coordination of Testing and Calibration Facilities (NCTCF) which started working and made its criteria based on ISO guide 25 for competence of test and calibration facilities. NCTCF recognition was given to various government and private laboratories. NCTCF had two programmes one for calibration and one for testing. Calibration programme of NCTCF was implemented by CSIR-NPL. Assessors for Calibration were initially provided by CSIR NPL and as the volumes grew, further manpower was trained by NPL to run these programmes.

Accreditation refers to third party recognition of capabilities of the organisation being accredited. As described by Aswal [26], accreditation is essential part of quality infrastructure of India. The NMI (NPL), Standard writing body (BIS), Legal Metrology Departments were setup in pre independence era or soon after independence. It may be noted that plans for accreditation of testing and calibration Laboratories were initiated in India by DST as early as 1980 and laboratory recognition activity was started by National coordination of testing and calibration facilities NCTCF and later by National accreditation board for testing and calibration laboratories NABL (1992). The scheme was coordinated by DST and worked from DST and NPL.

With liberalisation in 1991, the need for conformity assessment (CA) infrastructure came to forefront; a committee comprising various stake holders was setup to formulate a system that would enhance international acceptability of CA results. The proposal for such a system was prepared by department of Industries recommending establishment of an entity, with partnership between government and Industry, which was required to be self-sustaining and be away from Government [57, 58]. As a result of the proposal being accepted by government, it was decided to set up Quality Council of India with an aim of having an accreditation structure in India and for proliferation of quality movement in India through a National Quality Campaign. NABL was merged with QCI in year 2017.

QCI provides awareness and training through its various boards. These boards make efforts for spreading awareness in the area of Metrology, organise training, awareness workshops and capacity building. For example, their training programmes cover standards like ISO 17020; ISO 17011, ISO 17065, ISO 15189, and ISO guide 34, ISO 17043 etc. QCI has initiated consolidation of these efforts, by establishing an independent division ‘Training and Capacity Building (TCB)’ under its ambit. Among QCI Boards, NABL runs awareness and basic training programmes on metrology with faculty from NPL [57]. CSIR NPL has played a role in formative years of NABL to create human resource needed in the areas of its operations. Course on ISO Gum were done by NPL, region wise all over India, in order to provide training and have harmonised practices in India.
Training in area of standardisation is also taken up by BIS, which came into being for this task on 6 Jan 1947. It may be recalled that about the same time CSIR NPL also came into being. Thus, ISI was to formulate standards and testing for compliance was taken up by NPL in addition to its mandate for standards of measurements. With passing of time and due planning, Certification Marks Scheme, under the Indian Standards Institution (Certification Marks) Act, 1952 was started in 1955-56. Legal status was granted to ISI’s functioning by BIS Act 1986 [63]. NPL cooperates with BIS and provides expertise necessary for their course’s scenario. As a partner in QI, BIS also performs the task of training in standardisation and has established National Institute of Training for Standardization (NITS)’ to cater to the demands of the industry for training standardisation, certification and quality management [54], etc. NITS like NPL also conducts programme for developing countries of Asia, Africa, Europe and Latin America every year [54]. NPL’s expertise is availed by BIS as and when required. For example, when implementation of ISO GUM was picking up in India, NPL faculty has been nominated to teach these at BIS courses also.

Another important pillar of QI is Legal Metrology which is in purview of department of consumer affairs. For any country, legal metrology is vital for fair trade and to protect consumers. Director, Legal Metrology is a statutory authority with powers and responsibilities prescribed under the Legal Metrology Act, 2009 and has the responsibility for establishment of standards of Legal Metrology and keeping these standards traceable [56]. Legal metrology has Regional Laboratories, HR of these get training on job. Legal metrology officers are recruited with S&T background and trained further at Indian Institute of Legal Metrology, Ranchi, [64]. Further, it also liaisons with National Physical Laboratory for training of legal metrology officers in the areas of SI units, length, mass, pressure, temperature, time and frequency etc. The new recruits of legal metrology are sent to NPL for training in areas of mass, length, pressure, and temperature metrology. Time standards’ training has also been added to this portfolio.

20.3.2.4 Creating Awareness of SI, Quality Infrastructure and Development of Scientific Temper Among School Students

NPL India believes in imbibing the culture of metrology to Indian citizens from very early age (Fig. 20.10).

With this aim it has been decided to motivate the school students to pursue science of measurements and to have a rendezvous with measurement standards. Visits of School students and summer projects are organised to let them have glimpses of Primary standards-the deities of the measurement world. These activities include most accurate standards of mass, length, time, voltage, current etc. The subject is made simple through use of working models and exhibits including audio-visual shows on the scientific activities of the laboratory. CSIR-JIGYASA programme which is a student - scientist connect programme launched by the government, is one of such programmes [65, 66]. The programme is implemented by the Council of Scientific and Industrial Research (CSIR) during its Platinum Jubilee Celebration
Students from tertiary education system are groomed by NPL India with experience on sophisticated instruments during their training and dissertation. The metrology awareness and the experience are useful for their future. Figure shows number of UG and PG students, trained year wise

Year in collaboration with Kendriya Vidyalaya Sangathan (KVS) at national level for further widening and deepening its Scientific Social Responsibility (SSR). In 2020, CSIR also tied up with Atal Tinkering lab mission and is connecting to students other than KVs through this Mission. The focus of these scheme is on connecting school students and scientists so as to extend student’s classroom learning with well-planned research laboratory-based learning. Under these programme students of KVS are connected through three modes- visit to the laboratories, scientists visit to school and summer projects. CSIR NPL is providing the base for metrology training to these students.

20.3.2.5 Programmes for Student Trainee from Educational Institutes

UG and PG Level

Concepts of metrology aligned with international vocabulary of terms in metrology and ISO guidelines on uncertainty in measurements should ideally be included in university syllabus but this is not the case in India. To fill up this gap in education system CSIR NPL is taking steps by training of UG and PG students. Science and technology students perusing graduate or post graduate courses in India work at NPL as a trainee for their dissertations. The duration of these programmes is usually between two months to one year. These students get hands on experience with highly sophisticated instruments that are useful for researchers and learn R&D method during the phase of life after which they are going to start professional carrier. Uniqueness of carrying out such dissertation in CSIR NPL is that, besides the development of skills in Physics, chemistry or engineering science and technology, they also get exposure to methods used by metrologists. This exposure is
very much required for industries and academia. Hands on experience of measuring instruments enriched with metrology concepts makes these students ready for the job and enhances employability.

20.3.2.6 Higher Education like Ph.D. courses

NPL India is running Ph.D. programme and encouraging students to undertake Ph.D. in the various aspects of Metrology including Material’s Metrology as illustrated in Fig. 20.11. Ph.D. scholars started working in NPL from early years of its inception. Initially they used to work with various universities, this had advantage of diversification of work however, and such multi university cooperation had its own share of problems too. With setting up of Academy of Scientific and Industrial Research (AcSIR) [62] in 2011, NPL tied up with AcSIR through the MOU between CSIR and AcSIR. NPL is one of the largest centres of AcSIR for Ph.D. Figure 20.12 shows number of students enrolling for Ph.D. work at CSIR-NPL has been increasing; this may be attributed to increased awareness of NMIs role.

Several students are enrolled in Ph.D. programme who are working in problems related to Metrology. Today more than 300 hundred students are pursuing their doctorate research at NPL. As it has been discussed in the previous section, these students can be an asset for any laboratory/company/industry/academic institution they join. During their Ph.D. program they undergo detailed course work which

![Fig. 20.11 Areas of Ph.D. work at NPL cover science technology and metrology for physico mechanical, optical, electrical and electronics, environment, biomedical, chemical, materials, devices, Bhartiya nirdeshak dravya (reference materials), time and frequency](image)
Fig. 20.12 Number of Ph.D. students shown year wise. Working with a national metrology institute has an advantage of strengthening core science and technology research as well as metrology and quality systems skills.

includes quality system and basic metrology. Having in-depth knowledge in the subject these students can directly be absorbed at higher positions in academics as well as in Industry. They have an edge over their competitors due to hands-on training and learning extended by CSIR-NPL. Learning of metrology catalyses innovation and help bridge the gap between technology development and product development [67, 68].

20.3.3 NPL’s Efforts for Uplifting SAARC and Other Nations

SAARC nations have realised the importance of quality infrastructure and have made efforts in last two decades to develop the QI. Nepal and Sri Lanka have come up with their NMIs offering training course. NMI of Bhutan is coming up whereas some like Afghanistan are still struggling to establish and investing on development of human resource with courses from other NMI and LM institutes. The need for metrology usually arises in the beginning for protecting the interest of consumers. Weight, length, volume, temperature are the initial key areas that are needed by the LDC. Thus, the starting point of quality infrastructure is setting up a body for national measurement and legal metrology. At this stage need for imparting knowledge to managers, policy makers and the measurement personnel arises. Afghanistan is slowly overcoming these hurdles.
In developed countries education efforts for metrology are made and QI infrastructure is strengthened, further the developed economies have been doing capacity building of the developing and underdeveloped economies in terms of providing training and knowledge sharing. As a result developing and under developed nations build quality system, accreditation bodies and legal metrology system in their countries. Further examples from past are the aid from Germany to India in 80’s and 90’s, from JICA to Thailand and from PTB Germany’s initiatives for upgrading quality infrastructure and enhance regional cooperation in the SAARC region. German government supports development of metrology in developing nations through its NMI-Physikalische Technische Bundesanstalt (PTB) under various projects such as SAARC-PTB programme [69] and Metrology-Enabling Developing Economies in Asia (MeDEA) [70] project and various projects. Similarly European commission and many other donors provide support for the cause of metrology development [71, 72]. These are the examples of handholding made available to developing nation and upgrading competence of the national QIs. One may wonder why developed nations care for metrology HR development in developing nations. Let us try to understand this example by considering a situation where Items are exported from a developing or least developed economy as depicted in Fig. 20.13. Now if the economy ‘A’ with

![Diagram](image)

**Fig. 20.13** Measurement capacity building is needed to support export–import as it can minimise losses due to retesting and rejection
a weaker QI is the exporter and importer is a quality conscious nation with well laid conformance criteria, the measurements required to decide upon conformance in economy ‘A’ will not be relied upon by ‘B’. On reaching ‘B’, the receiver arranges retesting of the item and invests time and efforts to find out compliance. If the exported item fulfil the conformance criterion laid down by developed economy then only the product is put in use else both the economies suffer losses. Hence the metrologically advanced nations resort to the development of HR in QI of the nations which are major supplier or potential suppliers for them.

Many donors like UNDP, European commission for trade, German Government (through SAARC PTB Project) have come forward to support the SAARC in its ventures for HR in metrology. SAARC PTB project harnesses the expertise available in the region and catalyses the intra-regional cooperation in metrology.

CSIR NPL realises that the world of metrology and conformity assessment is very much interlinked internationally. Growth of a nation cannot be in isolation from its region and other interregional networks. Young researchers from various nations visit NPL from time to time. The state of metrology in commonwealth countries was of concern in international arena in eighties, a Common wealth India Metrology (CIMET) centre was established at NPL to provide group as well as individual training to participants from commonwealth countries. The centre worked under the advice of Dr A. P. Mitra, then DG CSIR, Dr S. K. Joshi, then Director NPL and Dr K. Chandra from India and other member from Barbados, Australia, Ghana and China. NPL also cooperated with centre for science and technology of the non–aligned and other developing countries (NAM S&T centre) to organise training course in metrology. These programmes continued till 2003. A number of delegates from various countries attended training programmes on basic metrology. Metrology concepts in various parameters like dimension, mass etc. and also training on quality system for ISO 17025 continued till 2003 under CIMET training programmes [47]. In later half of next decade empowerment of human resource with knowledge and skills for metrology was initiated for SAARC. A programme was prepared with funding from German Government and technical expertise from NPL. Under the SAARC-PTB programme, personnel from NMIS of Afghanistan, Nepal, Pakistan, Bangladesh, and Sri Lanka have been imparted knowledge. This support is still continued. It has made impact in the region and NMIs and accreditation structure has come up well in three countries others are also on the road to success.

20.4 Job Opportunities in the Field of Metrology

Scientists, Engineers and Technicians are the promising careers in metrology. Their qualifications differ according to the position and needs of the institute/industry. A job in metrology means understanding accuracy, precision, systematic bias/variances, evaluation of measurement uncertainty and traceability. In fundamental or basic metrology, the target outcome is to establish and perceive new units, devise new
measurement methods and/or to upgrade them with better accuracy and lesser uncertainty, build standard references, and to practically help implement the adherence of every industry to the traceability protocols. Near exact measurements are essential in all fields of measurements, especially in trade and commerce. For the latter, operational skill sets associated with instrument and its working principles become very important, and these individuals in metrology pursue their career as engineers and/or technicians.

A career in industrial metrology implies knowledge in specification of tolerances and high emphasis on the inspectional requirements, involved at the very outset of the production processes itself. Such teams need to have expert engineers with multi-level competences, which include understanding of the measurand, design and modelling with advanced technologies and certainly communication skills. Engineers are responsible for making detailed reports of the instruments and hence are required to possess knowledge of the quality control manuals.

A career in legal metrology is about regulation, in relation to the mandatory technical and legal requirement. The focus of this important branch of metrology is to ensure public guarantee in terms of security and accuracy of weights and measures. They include protection of public health, public safety, and the environment.

A plethora of jobs in metrology are those related to calibration technicians. This group of people work with a variety of advanced machinery and simultaneously performs several numerical, analytical and statistical procedures. Calibration technicians in some countries are also known as calibration inspectors or metrology technicians. In common, calibration technicians are anticipated to have good vision, adequate mathematical skills, knowledge of the principles underlying the equipment functionary, good eye-hand coordination, and also good communication skills. They also are required to interpret data and other relevant information in order to achieve the calibration procedures.

### 20.5 Challenges and Proposed Solution

Having discussed the need for Metrology education in India, it clearly emerges that there is a lack of focus on metrology education in Indian education system. Education system has to cater to the needs of various levels and sectors of employment. Science and Technology workforce coming out of educational institutions is struggling to find suitable jobs, on the other hand businesses also are facing difficulty in getting the needed skills [3]. Global competitiveness report highlights that the industry/Business should have a say in curriculum/education. India is in transition from developing to developed nations, focus on science, technology and Innovation has shown results. India ranked fairly well on research and innovation in global competitiveness. We are shifting from price based economy to innovation and quality based economy. Standards foster innovation [26, 67, 68], compliance to standards is enabled by metrology, which in term is performed/design by human resource. In view of this, a strategic intervention is necessary to reengineer the courses and
accelerate learning for precision measurement. The system has to adapt to changing international standards quickly. A gap between floating of new norms and its adaptation in India will lead to losses due to noncompliance and rejection. The challenge is to plan and implement this intervention quickly as well as effectively.

As mentioned earlier many countries have made recommendations and taken steps to mitigate the weakness of metrology education. In case of Lithuania, they started full time course and made four levels of metrology education with detailed planning of competence evaluation and management. Brazil’s Human resource metrology program evolved in many stages from 1995 to 2006 and has become a reference course in the region. Bosnia and Herzegovina implemented metrology education by pooling in capacity of various educational institutes in a consortia approach [34].

The discussion on the education system presented in Fig. 20.2, identifies that there is an impediment in terms of skilling and metrology in our education system. Few of the reasons that one could identify on a cursory glance are:

a) School education does not include theory and practical related to measurements concepts
b) Vocational training does not build up metrology skills
c) Degree programs with outdated syllabus, No exclusive degree programme in Metrology
d) Lack of state-of-art infrastructure for developing measurements skill.
e) Quality of teaching

Although each state has its own freedom to implement the educational policies and strategies, in many cases the curriculum design appears to have failed to consider the local issues.

For India a strategic planning and intervention is required to bridge this gap of metrology knowledge as described in Fig. 20.14. Strategic planning is needed to solve the problem through restructuring the education system, skill development through short term training or full time courses and a certification scheme for personnel. It may be noted that the education falls under the ambit of ministry of human resource. Ph.D. programmes are carried out in areas of thrust as decided by STI policy (Ministry of Science). Ministry of Consumer affairs oversees standardisation, legal metrology and accreditation whereas the National Metrology Institute is under Ministry of Science and technology. Most heavy Industries in public sector which are product of MSME are aspiring to be globally competent. Regulators in various sectors fall under different ministries.

The proposed solutions are discussed in Fig. 20.14.

(i) **Strategic intervention in Education System**

Fit to proper education is job or job creation. Quoting Maimonides, “Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime” holds quite appropriate in the present case of increasing unemployment problem. On one hand there are sectors like accredited laboratories, QC and QA in manufacturing industry etc. that are facing problem of metrology HR, on other hand there is unemployment. Education system and curriculum needs to be restructured
Fig. 20.14 Addressing the need for HR in metrology- requires strategic plan with consultations of stake holder, establishment of infrastructure for industry education. It is also important to achieve quality and equity of freelance trainers and certification of metrology personnel. Various levels of metrology training are needed as described in bottom left. Local economy along with QI can drive India’s global economy to solve these issues. The MSME sector takes most manpower right from school or vocational courses like ITI etc. Hence endeavours should be made in education system right from beginning.

A multipronged approach involving its secondary and tertiary education is suggested. It may be noted that the education falls under the ambit of ministry of human resource. Ph.D. programmes are carried out in areas of thrust as decided by STI policy (Ministry of Science). Ministry of Consumer affairs oversees standardisation, legal metrology and accreditation whereas the National Metrology Institute is under Ministry of Science and technology. Most heavy Industries in public sector which are product of MSME are aspiring to be globally competent. Regulators in various sectors fall under different ministries. A comprehensive policy needs to be designed and in order for it to be effective, authors are of the view that a consortium of various stakeholders and participation of all these stake holders is must. First challenge will be sensitising and synergising all to understand the urgency for development of HR in Metrology. This consortium, once synergised will make recommendations for policies and invite UGC, AICTE, etc. to focus on metrology and other needs of industry, academics and STI.
It is further proposed that the chapter on SI unit in secondary education may be elaborated to include all the seven SI base units and their importance to motivate the students right from young age. Also, the basic definitions as laid by the VIM document of metrology can be well introduced at this level. Scope of statistics, which is an essential tool in measurement science, should be widened to emphasize on the statistical tools to envisage the meaning of the basic laboratory experiments pursued in the school laboratories.

Several institutes and universities of India have now implemented metrology as a credit course of metrology like engineering metrology at the Bachelor’s level. Basic terms of metrology, traceability, working knowledge of various standards used in everyday practice in the field of electrical, mechanical and electro-mechanical, biomedical, and chemical measurements should be part of mandatory core syllabus. The contents of the course is expected to benefit students to pursue a career as laboratory technicians involved with testing and/or measurement, Six Sigma ($\sigma$) practitioners, quality control specialists, for engineers and technicians involved with manufacturing facilities and developing critical-to-quality specifications on components and assemblies, etc. Vocational training should focus on basic concepts and more practical knowledge of measurements in the specific sectors. Besides this, skilling and up skilling should be carried out. The scope of such education is wide and expertise are available in the country but at different places in fragmented manner. Partnership of various tertiary education Institutes as well as vocational training Institutes with NMI and regulators can achieve this ambitious target.

Three Levels of education and skill set may be defined for industrial metrology (Shop floor technician, Inspector and Engineers) in line with recommendations of skill Council. Fourth level will be highly specialised metrologists for scientific metrology and train the trainer schemes. A personnel certification scheme operating as per ISO 17024 criteria is proposed. NMI can play a great role in designing the scheme (Fig. 20.15).

Education policy is to be formed by involving various stake holders from industry, government, educational institutions, accreditation and standardization bodies and national measurement institutes. Though NEP 2020 recognises need to involve industry in technical education, explicit involvement of Industry in making policy itself and syllabus will ensure their needs being identified and taught right from beginning and will enhance the employability. Involvement of NMI, quality infrastructure and regulators will again make the system robust and fulfil the need of skill building suitable to these areas. Nationwide implementation of the policy is to be carried out through education Boards, University Grants Commission, All India council of technical education, Medical education research institute, MHRD Institute and National laboratories with educational institutes for tertiary education and vocational educations. Use of information technology should be made to enhance training in these areas. There can be programmes for trainers, beginners and practitioners. These measures will benefit Industrial metrology and elements of QI namely legal metrology, standardisation, testing and calibration labs, accreditation bodies and new recruiters of NI. However for NMI and regional labs of echelon 1, there is a need for high end programmes like doctorate to prepare HR for scientific metrology. Such
doctorate programmes can be offered by cooperation between NMI, and improvement by feedback from targeted beneficiaries as shown in Fig. 20.15, is expected to give good results.

(ii) **Skillling of workforce of India and availability of career progression Routes**

Skill development has to include metrology training and keep on building it with advancements and adaptation of new technologies in workplace. Individual level expertise is essential to perform a certain job which is utilized by the employer to perform that role. Competency of the team is requirement of the organisation which depends on competence needed by individual for a specific role and complementing the skills of individual to achieve team targets. Skills can be segregated into a hierarchy based on **immediacy, relevancy, and feasibility** [59]. Proficiency, which is needed currently or in forthcoming days, comes under immediacy. The relevancy of ability or aptitude can be assessed based on the ease of transfer of training from a learning atmosphere to the actual work atmosphere. The feasibility of proficiency refers to the potential of the skill to stay relevant in the future. With this hierarchy in place, a plan in terms of the requirement of organization regarding training, hiring, up skilling etc. can be decided more strategically and make the best use of the talented employees already on board.

Career progression is a very important aspect that needs to be taken care of, for existing metrology workforce. Due to lack of structured metrology program, education of metrology is obtained in general on the job. It becomes imperative to provide career progression to experienced individuals who learnt the skills while carrying out day to day calibration or testing activities. Performance improvement can be targeted by skill training which often results in further improvements in the potential of such personnel. If the person of lower qualification shows potential, continued education programmes should be offered which encourages and motivates
the worker further. Practical experience gained by the person in parallel to acquiring further education and training on advanced technology can be helpful in taking mid potential/mid performance person to high performance one (Fig. 20.16).

This becomes a very crucial stage where complacency needs to be broken by aligning personnel growth goal to organisation growth targets and strategic intervention of mentoring, training and providing motivation by enlarging their roles. Further impetus for growth can be through measures like accelerated position and role growth and international exposure. Thus, within the organisation the human capital on lowest paddle of career growth can also aspire to reach highest paddle and thus remain motivated. Training of metrology that organisations build in the system will not go waste and a goal oriented HRM can provide the best returns on this investment.

The training of metrology is in line with the missions of ‘Self-reliant India’, ‘Vocal for Local’ and ‘Skill India missions’. It is expected to enhance employability of personnel, benefit the industry, help economic growth and improve quality of life.

(iii) Certification scheme

Personnel certification program is proposed for the certification of metrology personnel. The programme may be developed to meet requirements of ISO 17024:

The personnel certification will be based on the technical criteria and basic qualifications set up in consultation with stakeholders. The focus of metrology education can draw an analogy with computer education focus in nineties. Department of electronics had once come up with open learning course curriculum, with O level, A level curriculums and authorised centres for learning. Thus, having such open education

![Fig. 20.16](image-url) Proposed scheme for continued education and up-skilling to retain the manpower and help the trained metrology personnel to reach higher positions
done, a person could appear in exam and get certified. Even working professionals could add up this qualification mode.

Today we have the need for certification in metrology. As discussed, metrology knowledge is required by operators, testing and calibration technicians, engineers and metrologists. In line with these requirement Level 0, Level 1, Level 2 and level 3 certifications are proposed. **Level O** will be beginner’s level targeting operators, basic qualification can be 12th.

### Level 1

For Level 1 calibration tasks, testing SOPs, detailed calculation of uncertainty of measurement as per ISO GUM, Inter Laboratory Comparison (ILC) report preparation, knowledge of QI should be included in the curriculum. Basic qualification can be 12th plus 3 years’ experience in metrology or ITI plus one-year experience or Diploma

### Level 2

For going to Level 2 person must be able to perform error analysis of at least one test or calibration task, have experience of calibration and testing and ILC. The further learning at this stage would be compliance standards, quality management standards, process control tools, validation of new methods etc. Basic qualification can be 12th plus 5 years’ experience in metrology and certificate, or ITI plus 7-year experience or Diploma plus three-year experience or Graduation in science/Egg. and passing level 2.

### Level 3

In addition to skills of level 2, at this level knowledge of relevant quality measurement standards, development of SOPs, design of metrology experiments, development of new methods and validation, piloting intercomparison is the skills targeted in curriculum

Basic qualification will be Masters of Science and technology.

Course content and study material needs to be developed by NMI, STQC, ARAI, IDEMI, and other national laboratories. A flexible public, private partnership (PPP) can be implemented where accredited laboratories can offer practical learning in various cities and theory classes can be run online by the NMI or national labs. The recognition of these learning centres in PPP mode will have a cascading effect and develop metrology HR in timely and targeted manner.

Certification agency will work based on these criteria and tests developed for each level and fields. The personnel certifications programs will assure that workforce fulfil minimum quality standards specified for each level.
20.6 Conclusion

This chapter portrays the need of HR development in metrology which is not given its due importance in education system. It further presents the national and international scenario of HR in metrology and its relevance to quality infrastructure of Nation. Nationally mostly the metrology is being learnt on the job and through short training programme. The chapter presents a detailed review of present scenario and the courses available nationally and internationally. The development state of a country is related to development of metrology in the nation. Developed economies have a robust quality infrastructure and prepare the human resource for it. From the review presented it can be concluded that India has lots of challenges to face in terms of HR for metrology. CSIR NPL is trying to meet some of the challenges; the efforts of CSIR-NPL for development of human resource in metrology have been presented here. CSIR-NPL is fulfilling the need by a dedicated full-time course/training for industrial metrology and preparing high end skills for scientific metrology.

Review of metrology in curriculum exhibited that there are some initiatives to introduce engineering metrology, launching e-courses like Swayam portal of Indian Government. Further, a large number of organisations and individuals are also offering short term courses in India. Managing equivalence of such programmes and evaluation of competence is a challenge. Significantly, it includes the highlights and contributions of CSIR-National Physical Laboratory, in training HR for metrology by short courses, a full time one year PG diploma and Ph.D. programme under AcSIR [62]. Short courses offered by NPL to industry people, various companies and calibration laboratories leads to utilization of experienced employees in their organization with updated knowledge. In the same line NPL is also helping other developing countries by way of training and advice.

Analysis of gaps, challenges has been made and solutions are proposed for tackling the problem through a scheme for education system, personnel certification, skill developments and capability enhancement coupled with availability of career progression.

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