Situation of Metrology Education in Developing Countries using Nigeria as a Case Study

S.M. Ibrahim, P. Bills, J.M. Allport
University of Huddersfield
United Kingdom

Abstract

Metrology is quite an unusual profession, but it is widely encountered and very significant in our everyday life. However, metrologists are few and most universities don't even mention the subject. How, then, do metrologists get an education? This paper aims to address metrology education in developing countries, to enhance developing countries' awareness of the significance of metrology education and the need for it to be introduced into universities academic curricula.
The impediment of metrology education is much more widespread in developing countries than the developed countries. To substantiate the level of metrology education in developing countries, Nigeria has been used as a case study. Research which examined knowledge related to metrology in general, flow and legal metrology was conducted across six Universities. Assessment of the students revealed they substantially lacked the abilities required in all area of metrology knowledge.
Considering the general significance of metrology, this paper therefore recommends that the curricula of engineering schools, technical universities and other special training institutes should contain at least some basic courses on metrology. Also recommended is the formation of consortia of institutions comprised of educational institutions, industry practitioners, and regulators. This paper also highlights the requirement for a suitable metrology education for practitioners within statutory bodies.

1. Introduction

Metrology (the science of measurement and it applications) is quite unusual as a profession but it is encountered very widely in practice, from measurement systems or instrument design to calibration works, scientific research, and everyday life. Some aspects of metrology concern the establishment of quantity systems, unit systems and units of measurement; the development of new measurement methods; realisation of measurement standards and the transfer of traceability from these standards to users in society. Others cover the application of measurement science to manufacturing and other processes and their use in society [1], while yet others are concerned with applying regulatory structure and enforcement to metrology. Some practitioners design measurement systems or instruments. Others perform calibrations. Still others do basic research into underlying scientific principles. The legislation of many new products and technologies depends on metrology [2].

Metrology is an integral component of the technical infrastructure value chain. Traceability to national measurement standards, which is one of the key element of metrology, is fundamental, for instance, to the optimisation of disease diagnosis and health care, forensic science, occupational health and safety, production, consumer confidence and protection, food safety and environmental monitoring,. Principles of measurement and observation remain fundamental regardless of application, they apply to every measurement and observation made in every lab anywhere on the planet. As noted in the study of Vosk [3], physicist Lord Kelvin said over a century ago, "…if science is measurement, then without metrology there can be no science".

Metrology is multi-disciplinary. In application, it enables measurements of quantities to be related to one another in a true and absolute sense. Measurement is the essential tool by which humans describe the world and reason about it. If measurements are flawed, analyses and interpretations based on these measurements are fundamentally and irreparably fallacious [4]. Considering the large variety of applications in the field, one can imagine how broad the subject matter is.

Metrology is everywhere, but specialist metrologists are few and most curricula in technical fields don't even mention metrology. How, then, do metrologists acquire an education? Considering the significant of metrology, it is necessary to create awareness of the need to introduce metrology curricula into those scientific and technical fields in universities, most especially in the developing world. With the increased emphasis on the equivalence of measurement and testing services for quality of life, environmental protection and trade, this is particularly important for the economic development of those countries. This paper considers with

particular interest, metrology education in developing countries with the aim of enhancing those countries' awareness of the significance of metrology education and the need for it to be introduced into university level academic curricula. This paper will also provide background information on educational institutions offering metrology programs or classes in developing countries for the benefit of the prospective students.

2. Importance of metrology – Why do we measure?

Metrology in support of efficiency and innovation in industry is not, however, the only subject of this paper. This paper will speak about the impact which measurements make on all of us in our everyday lives. We benefit from a wide range of measurements which are routinely carried out in our interest, many of which go unnoticed. As illustrated in Figure 1, measurements are met in almost all human activities.

Figure 1. Metrology benefits [5]

The following briefly describe the significant of metrology, although it is a far-from-complete list of some of the larger and more important fields of use:

i. Metrology aid in industry: Metrological characteristics undoubtedly, concern industry. Industry has to set up analytical systems in such a way that they allow modifications in procedures and adaptation to analytical progress without harming internal comparability. This includes the maintenance of traceability for basic measurement methods (masses, time, etc.). For biological and chemical measurements, it also implies that well validated methods are utilised [7].

Moreover, on the issue of industry needs of metrology, the industrial sector usually incurs errors due to bad measurements and data processing. These translate into waste, bad quality, production decreases and impact on their finances. It is therefore important to recognize the errors and their causes and to be able to have trust in the measuring instruments [9].

Metrology at the technological frontlines enables and facilitates industrial innovation in advanced production and instrumentation [6]. Through the development of measurement techniques, metrology enables innovation of products in many areas, such as in healthcare and assisted living.

Metrology plays an indispensable and integrated role in the automobile industry. Accurate, comparable and traceable measurements of almost all physical quantities and several chemical quantities (e.g. exhaust emissions) is vital for constructing innovative, low-cost, low maintenance, safe, energy-economic, and environmentally friendly cars in an extremely globalized and internationally competitive market [7]. Dimensional requirements are stricter than ever at the spearhead of some industrial techniques like electronic miniaturization. Seamless interchangeability of components is commonplace owing to gauging and accurate measurements made possible by the advances made in dimensional metrology field [8]. Thus, when conversing about the significance of metrology regarding length measurement, it is not a matter of aggrandizement, but dealing with a very genuine practical need for national economy.

ii. Metrology aid in commerce: In commerce and industry everything is being measured. Thus, the importance of metrology as a science of measurement just can't be ignored. Measurements enter into practically all commercial transactions from the trading of goods to the retail sale of goods in the market place. For example, in oil and gas industry major trade benefits would be obtained if the measurements of flow were significantly more precise, as billions and billions of barrels are measured in oil and gas pipelines and then traded to users. Errors of a few parts per thousand represent some hundreds of millions of dollars [14]. Consider the case where a Pump Station was designed to pump 60,000 gallons per minute (227 cubic meters per minute) of oil. A small error of 0.1% equates to an error of 2,057 barrels of oil a day. At a spot price of $105 a barrel, that 0.1% error would cost $216,000 a day. Over a year, the 0.1% error would amount to a difference of $78.8 million. Note that the error could either be on the high side, benefiting the seller; or on the low side, to the buyer's benefit.

At home, people consume electricity, drinking water, gas, heat, all of them measured by meters whose reliability is tested and approved by organisations within the legal metrology system. This is to ensure that these measuring devices will give correct results and that the specified error limits will be maintained during a period of predefined duration. For instance, according to International Committee for Weights and Measures [10], Western European gas consumption in 2000 reached just under 390 billion cubic metre, being about one-fifth

of total energy demand. One can clearly see that a metering error of 1 % equals about 4 billion cubic metres having a commercial value of 800 million euros per year at a consumer price of 0.20 euro per cubic metre.

Metrology improves fair trade via harmonised written standards, reliable measurement systems and methods, and universally recognized certificates. This makes it possible for a pre-package labelled "1 kilogram" in any nation to equate to the same measure of product in another nation; parts assembled in one nation fit into devices in another nation, machines type approved for use in one nation could likewise be sold and utilised in another nation, without extra technical inspections [6].

iii. Metrology improves health and promotes the safety of citizens: Calibration and testing of medical devices are some of the most important and critical issues in the field of metrology. Test, measurement and calibration are critically important in achieving quality control of the highest standard in medical equipment. Confidence in medical measurement results helps in deciding if medical treatment is needed or not [11]. When dealing with medicines, incorrect doses can be dangerous. Under dosing may not adequately treat an illness. Overdosing, on the other hand, may cause illness or side effects that can be lethal. This clearly shows that measurement errors in diagnoses and in therapy can cause serious problems, or even death and, for good or bad, we rely more every day on measurements related to health.

Apart from its positive impact in health and safety, measurement is also critical in saving cost. When medical results are accepted and usable everywhere, unnecessary repetition of possibly detrimental diagnostic procedures such as X-ray exposure which could be costly will be minimised. Moreover, during the X-ray exposure the required dose of radiation will not be exceeded [5]. Accurate calibration of medical instruments supports precise and correct diagnosis of disease.

iv. Metrology in aid of food safety: The safety of the food we consume has a direct impact on our well-being and is a determinant for the quality of life. Food testing and the metrological principles associated with this activity play a key role in helping to ensure the safety of the food chain. Food testing is closely associated with public health, chemical and biological testing is used to make decision about food quality. Thus, reliable sampling and measurements are an essential component of proper decision taking [10]. Through certified reference materials, legal metrology provides confidence in these results.

v. Metrology aids in environmental protection: Environmental and climate concerns affect our lives, regardless of where we live in many more aspects than we might suppose. Accurate measurements of atmospheric parameters such as air and water quality, electromagnetic and noise pollution, radiation level and extreme meteorological events are fundamental everywhere on our planet. The degradation of the environment from the damaging effects of human and industrial activities be it in the ground, water or in the air, must be measured accurately. Apart from its positive impact in ensuring reliable data for checking conformity to standards and for decision-making related to protective measures, it is also critical in saving cost. For instance, when formal arrangements for emission trading become operative, the costs connected with keeping the environment clean or connected with the cleaning process itself are enormous. Incorrect measurements lead to wrong decisions and may cost the producer or society very large sums of money according to International Committee for Weights and Measures [10].

As we base our lifestyle on so many indirect environmental impacts, e.g. large scale industrial and power plants, each of them require monitoring, measurements and controlling at levels of uncertainty close to, if not equal to the state of the art. We need to improve data quality in essential climate variables to better understand how our climate is changing. Measurements are the basis to guarantee reliable observations and organise mitigation actions for climate change.

vi. Metrology aids regulation: A range of government regulations cover areas such as environmental management, occupational health and safety, traffic control, and air traffic control. Metrology aids regulation by providing measurement references for policy advice, directives, conformity assessment, and verification [6].

vii. Metrology related to the quality of life: Many types of measurements are more or less closely related to what the public perceive as "quality of life". These include measurements of noise (e.g. noise from neighbours, traffic and airport noise), dust (outside and inside), vibration and even measurements of subjective quantities such as taste, smell and appearance (e.g. glossiness of paints is a well-known and critical parameter in paper and car manufacturing). Also in these cases the consumer expects reliable and comparable measurements and specifications [10]. Precise measurement standards can lead to better analysis and understanding of our living environment, for example indoor and outdoor air quality monitoring to protect and improve the quality of life [10].

3. The Current Situation in Metrology Education

Good metrology systems and qualified specialists can help in increasing productivity and efficiency, improving repeatability by minimizing human errors, increasing customer satisfaction and saving money applying new or suitable technologies for various tasks. Indeed, any nations with the prospect to develop must have an established metrology system which includes training centres, specialized educational institutions and formal metrology education at technical schools and/or university level. Given a basic understanding of metrology, even a non-scientist can begin to engage in a critical analysis of scientific claims across a broad spectrum based on metrological principles [4]. However, the establishment of new metrology systems embedded with qualified specialists in newly independent countries needs special education for the professionals involved in the process. Accredited bodies or personnel of calibration services must have some understanding of calibration, quality standards, regulation, laws and the benefits of them to the society at large. All of this requires some level of education.

Conversely, in many countries, there is inadequate provision for teaching of metrology at every level of the educational system: schools, technical colleges and universities. Metrology often has to be "learned on the job" [2]. In an attempt by the International Committee for Weights and Measures [2] to proffer a solution to this problem, it laid emphasis on training as an important issue that needs to be addressed nationally. However, what must be taken into consideration is that the teaching personnel need to be educated before effective training can take place.

Likewise, the control of Weights and Measures (Legal Metrology) via legal routes to ensure fair transactions and accurate measurements, has from ancient times been considered as an essential duty of a nation. This also demands the need for highly skilled professionals in metrology. As found in the study of Mason [12], the problem of shortage and inadequacy of qualified personnel in metrology has been a general problem that is hindering the progress of many developing countries. He therefore recommended nation to nation training, that is, nations that are most advanced in metrology provide significant training to those that are less advanced. Paradoxically, while it is necessary to use expertise acquired from abroad, it is not usually possible to transfer metrological methodology from the developed countries in a successful manner without the developing countries having a fundamental understanding of metrology.

Many years ago, the George Washington University partnered with the National Bureau of Standards (now the National Institute of Standards and Technology or NIST) to offer graduate programs in metrology, but today, such programs are no longer available [13]. Also, around 1961, the Navy Metrology Engineering Centre at Pomona, CA offered metrology courses in most measurement disciplines. After the mid-sixties, a Tri-Services agreement provided for gradual consolidation of the courses at Lowry. However, such schools is no longer in existence today.

Metrology is not just a pleasure to a very small number of specialized scientists, it is a practical profession, vital for industry development and to the economic growth of nations, although not always recognized as such, the term is narrowly understood even among the educationalists.

Table 1. Educational institutions that offering metrology courses in developing countries (15, 16)

EDUCATIONAL INSTITUTIONS THAT OFFER METROLOGY PROGRAMS OR CLASSES IN DEVELOPING COUNTRIES		
Countries	Educational Institution	Metrology Program
BRAZIL	Instituto de Pesquisase Estudos Industriais (IPEI)	Institute of Industrial Research and Studies
CHINA	University of China Metering, Hangzhou	Metrology and Measurement Engineering
KOREA	University of Science and Technology(UST)	
MEXICO	The Center for Engineering and Industrial Development (CIDESI)	Postgraduate Metrology Programs
	Universidad Politécnica de Santa Rosa Jáuregui	Engineering Industrial Metrology
MOROCCO	Ecole Spécialisée en Qualité et Métrologie 4, Rue national, Centre ville de Casablanca	Quality management system
	Nosov Magnitogorsk State Technical	Master in Engineering - Standardization

RUSSIA	University	and Metrology
	Siberian State Aerospace University	Standardization and Metrology
THAILAND	King Mongkut's University of Technology Thonburi (KMUTT)	Industrial Metrology Program
TANZANIA	College of Business Education, Dar Es Salaam	Basic Technician Certificate in Industrial and Legal Metrology
UKRAINE	LIVIV polytechnic University	Bachelor in Metrology and Information-measuring Engineering
	National Technical University of Ukraine: Igor Sikorsky Kyiv Polytechnic Institute	Metrology and Information-Measurement Engineering"
	National Technical University: Kharkiv Polytechnic Institute	Metrology and Information and Measuring Equipment

Table 2. Educational institutions that offer metrology programs or classes in developed countries (15, 16)

EDUCATIONAL INSTITUTIONS THAT OFFER METROLOGY PROGRAMS OR CLASSES DEVELOPED COUNTRIES		
Countries	Educational Institution	Metrology Specialisation
AUSTRALIA	RMIT University, Melbourne, Australia	Metrology Programs
	Macquarie University, Balaclava Road, North Ryde, NSW, 2109, Australia	Master of Laboratory Quality Analysis and Management
BULGARIA	South-West University 66 Ivan Michailov st., 2700 Blagoevgrad, Bulgaria	The bachelor program of Metrology
CANADA	Academy of Applied Pharmaceutical Sciences Inc., North York (Toronto), Ontario	
	Conestoga College, 299 Doon Valley Drive, Kitchener, Ontario N2G 4M4	Quality Assurance (Ontario College Certificate)
	Fleming College	Instrumentation and Control Engineering Technician
	Seneca College	Quality Assurance (Seneca College Certificate)
ESTONIA	Applied Measurement Science (AMS), University of Tartu	
FINLAND	Aalto University, Metrology Research Institute	Aalto University School of Electrical Engineering
FRANCE	Ecole Supérieure de Métrologie Ecole des Mines de Douai Dpt Métrologie-Qualité	Mastère spécialisé en Systémes de Mesure et Métrologie
	University of Reims Champagne Ardenn	Professional Undergraduate Degree in Sensors, Instrumentation, Metrology (CIM)
GERMANY	Braunschweig International Graduate School of Metrology (IGSM)	international metrological training centre
	Friedrich-Alexander-Universität Erlangen-Nürnberg FAU	MSc in Advanced Optical Technologies
LITHUANIA	KTU Institute of Metrology, Kaunas University of Technology	
IRELAND	Institute of Technology Sligo	BEng in Precision Engineering and Design

ITALY	Politecnico di Torino in convention with Istituto Nazionale di Ricerca Metrologica (I.N.Ri.M.)	science of measurement
SLOVAK REPUBLIC		PhD SJF 5.2.55. Metrology
SWEDEN	Department of Measurement Technology, SP Technical Research Institute of Sweden	Metrology and quality-assured measurement
UNITED KINGDOM	Coventry University	Foundation Degree in Metrology
	University of Huddersfield	Advanced Metrology
US	University of North Carolina at Charlotte Center for Precision Metrology 9201 University City Blvd Charlotte NC 28223	Center for Precision Metrology
	California State University Dominguez Hills Carson.	Certificate of completion in Metrology; Master of Science Quality Assurance
	California National University, Torrance	Bachelor of Quality Assurance Science Degree Program
	Northern Illinois University, Dekaib	Quality Control of Manufacturing Processes (Certificate of Graduate Study)
	Purdue University – College of Technology West Lafayette, IN	
	Eastern Kentucky University, Richmond	Applied Engineering & Technology
	Idaho State University, Pocatello	Master of Science in Measurement and Control Engineering
	Ferris State University at Grand Rapids, Big Rapids, Michigan 49307	Quality Technology, Certificate
	University of Central Florida, Orlando	Quality Assurance Graduate Certificate
	Vincennes University, Indiana, Haas Technical Education Centres, Vincennes	Vocational Metrology Training
	Alamo Colleges: St. Philip's College, 1801 Martin Luther King Drive, San Antonio, Texas 78203	Precision Tools and Measurements
	Butler County Community College, Butler, Pennsylvania	Measurment Science/Metrology Technology, A.A.S
	Central Community College, Columbus, NE	
	Central Georgia Technical College, Macon,	AAS Metrology; Metrology Diploma; Electrical Metrology Certificate; Physical Metrology Certificate
	Cerritos College, Norwalk	Coordinate Metrology, Certificate of Achievement
	Danville Community College, Danville, Virginia	Dimensional Inspection (Metrology)
	Fox Valley Technical College, Wisconsin	Production Inspection & Metrology (Certificate)
	Front Range Community College, Longmont	Manufacturing and Energy Technology - Associate of Applied Science Degree
	Joliet Junior College, Joliet	Dimensinal Metrology (Certificate of Completion (CCO))

	Madison Area Technical College, Madison Miwaukee Area Techical College	Dimensioning/GDT; Elements of Basic Metrology; Intermediate Metrology Applications Quality Engineering Technology, Associate in Applied Science Degree

US	Monroe County Community College Monroe,	AAS Metrology Technology
	Nashua Community College	Metrology and Quality Control for Precision Manufacturing Certificate
	Navajo Technical University, Crownpoint	Advanced Manufacturing Technology B.A.S.
	New Jersey Institute of Technology	Manufacturing Engineering Technology (MNET)
	Piedmont Technical College Greenwood, SC	Precision Metrology Certificate
	Red Rocks Community College, Lakewood	Metrology Quality Control Certificate
	Ridgewater College Hutchinson	Calibration and Metrology Technology
	Rock Valley College Rockford, IL 61114	Manufacturing Engineering Technology (MET) Degree
	Sinclair Community College Dayton, Ohio	Operational Technology

Considering the vast benefits of metrology depicted above, metrology is a unique program that needs to be incorporated into schools, technical colleges and universities academic curricula. Yet, the prosperity of this knowledge has not been evenly spread throughout the world. There remain considerable differences between and within regions, countries and societies. Too often, lack of metrological education has left significant segments of the countries affected behind. This is particularly so in the case of Nigeria.

3. Metrology in Nigeria

To demonstrate the level of metrology education in developing countries, Nigeria has been used as a case study. The oil and gas industry are the main source of Gross Domestic Product [GDP] in Nigeria with about $8 billion spending annually in servicing the industry, with the figure projected to hit $15 billion in next few years according to Omenikolo & Amadi [17]. Despite the huge sums of money spent on this industry, the Nigeria Extractive Industry Transparency Initiatives [18 and 19] audit report reflected insufficient measurement control across the sector. Since the degree of development of metrology in a country also reflects the stage of development of that country's industry according to Zaimović-Uzunović and Lemeš [20], execution of the measurement in the sector by non-experts in metrology or lack of metrological knowledge by the designated bodies in charge of the regulation of the measurement activities could lead to insufficient measurement control.

Taking into consideration the metrological knowledge required for effective measurement control to be achieved in the sector and the recruitment criteria of the bodies in charge of the measurement control of this industry which include: the oil and gas operators; the DPR (Department of Petroleum Resource) which is the body charged with the legal responsibility of regulating, monitoring and supervising the measurement activities in the industry; and the Weights and Measures Bureau (the legal metrology body bestowed with the responsibilities of supervising and ensuring accurate calibration and certification of measuring devices used for custody transfer measurement system and type evaluation and verification of all the measurement devices), the knowledge gaps of the students were evaluated in the areas of general, legal and flow metrology. This was to evaluate the capability of tomorrow's professionals relative to the metrological knowledge necessary to form stronger metrology bodies capable of maximising the economic recovery of Nigeria oil and gas through sufficient measurement control. The research has been conducted across six universities with the survey population of the study made up of students from engineering and science disciplines. The research examined knowledge required in basic, flow and legal metrology by intensive investigation

through interviews and questionnaires. The scope of the research comprised metrological knowledge that will enable new graduates to make productive contributions to the Nigeria oil and gas industry.

3.1. Survey methodology

The survey was conducted through a combination of interviews and questionnaires.
The interviews were designed to confirm the extent of the students' fundamental knowledge of metrology. The interviews were structured around the following questions:
Q1. What do you understand by the term metrology?
Q2. What are the benefits of metrology to the society?
Q3. What are the categories of metrology?
Q4. What do you understand by the term scientific and industrial metrology and their related field?
Q5. What is legal metrology and what is their benefit to the society?
Q6. What do you understand by the term metrological control and what are the basic elements?
Q7. What do you understand by term measurement uncertainty?
Q8. What do you understand by the term traceability of standard?
Q9. What is calibration and why calibrate?
10 What are the differences between verification and calibration?

For the questionnaire, since the oil and gas industry are a major user of flow measurement and the legal metrology bureau is responsible for the metrological control of the sector, the questions covered topics across a variety of subjects related to flow metrology and legal metrology. The questionnaire was designed to determine if the future professionals will be able to make a significant contribution to the management of the measurements activities in the Nigeria oil and gas industry. The questionnaire then asked 10 broad questions and offered several selections to rate on a scale 1(Unknowledgeable), to 3 (Knowledgeable). Questions 11 through 20 are as follow:
Look at the listed educational knowledge and skills critically and choose from the options base on your knowledge and skill level. Selection range: 1(Unknowledgeable), 2 (Somewhat knowledgeable) to 3 (Knowledgeable).

Q11. Principles and practice of flow measurements
Q12. Oil and gas custody transfer measurement system
Q13. Legal metrology requirements of oil and gas custody transfer measurement
Q14. Fiscal oil measurement uncertainty requirement
Q15.Fiscal gas measurement uncertainty requirement
Q16. How to inspect and verify gas measurement systems
Q17. How to inspect and verify liquid measuring systems
Q18. How to inspect and verify bulk storage measurement systems
Q19. Sources of error and mismeasurement within metering systems
Q20. Standards available for petroleum measurement

Respondents' identities and the universities with which they affiliate remain confidential; however, they clearly represent a cross-section of engineering and science students in Nigeria.

3.2. Results

The views of 1017 students of science and engineering disciplines were obtained. 25% of the students were in 500 level, 35% 400 level, 30% 300 level and 10% 200 level. The results of the interview and questionnaires were analysed using univariate descriptive statistics. Questionnaire with no answer were assigned an interest number of 0. The reflection of the self-assessment and assessment of the students with respect to their knowledge gap in metrology are shown in Figure 2 below.

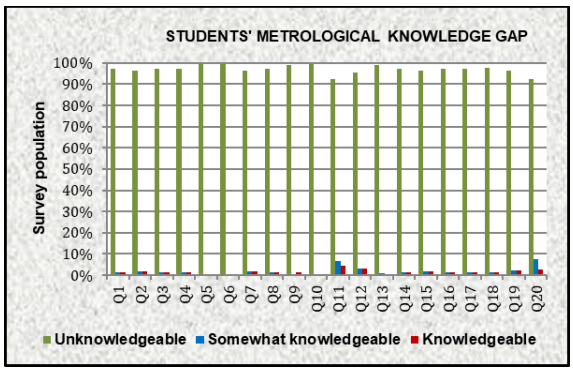

Figure 2. Knowledge gap of the students

As shown in Figure 2, in all the aspects of metrology examined, self-assessment and assessment of the students reveals they all certainly lacked the required competencies. Familiarity with legal metrology is below 1%. At present, based on the survey results, Nigerian Universities cannot produce graduates suitable for metrological development. Courses specialising in metrology have never been offered at either undergraduate or postgraduate levels. With the research outcome, one can deduce that the insufficient measurement control Nigeria is facing within its petroleum industry is due to the fact that most of the bodies in charge of the sector are insufficiently trained or experienced in metrology.

4. Recommendations

Metrology education is indispensable to developing countries for their economy and for attracting investment. Unfortunately, this subject area is generally weak within the educational institutions in the developing countries. While it is necessary to use expertise acquired from abroad as recommended by Zaimović-Uzunović and Lemeš [14] and Mason [6], developing countries must also make an effort to integrate metrology programmes into their academic curriculum.

In order to have manpower experienced in scientific, industrial and legal metrology to keep pace with the needs of industry and society, every country must have a well-established metrology system with adequate metrology training centres, specialized educational institutions and, of course, formal metrology education at technical school and university levels. In addition, the curricula of engineering schools, technical universities and other special training institutes should contain at least some basic courses on metrology. To facilitate this, consortia of institutions comprised of educational institutions, industry practitioners, and regulators also need to be formed.

Since before the field of metrology can advance in line with the growth in a particular branch of industry, it is necessary to provide the appropriate personnel [14], developing countries must also make an effort to penetrate the domain of metrology program. The program should consist of compulsory courses covering fundamental skills and knowledge about metrology; general courses dealing with more specialised and advanced topics; and elective courses where students are able to choose the courses which suit their professional needs. These will define the requirement for a suitable metrology education.

Thus, if we are going to secure the flow of talent into metrology, to enable purposeful and effective early intervention to enthuse tomorrow's metrologist, we need to start at the very beginning. An education and training in metrology is therefore essential for everyone, starting from primary education, though secondary education and in many cases higher education and professional training. Education is the means which will allow spreading metrology and its importance to society and to the industrial sector. The use of metrology as a basic tool of study and analysis allows assimilation of everything what surrounds us, from the simplest to the most complex thing.

The best mechanism of transferring metrological knowledge is by incorporating it into university academic curricula, no undergraduate course should go without these basic elements. The effects of this lack of knowledge are apparent already in advanced bachelor courses, during the master study and even in technical reports and papers.

5. Conclusions

This paper presents the significance of metrology and the weakness among the educational institutions in developing countries. The metrological knowledge assessment conducted across some Nigerian universities used as a case study provides clear evidence of the level of the weakness. Therefore, considering the importance of metrology to the development of a nation, it is crucial for the educational institutions in the developing countries to introduce metrology into their academic curricula.

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