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Metrology personnel competencies. Their importance to the quality of measurements

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ABSTRACT

Reliable measurements are essential in today's world for a variety of reasons. Accurate and consistent measurements are crucial for decisions in a wide range of fields, including science, engineering, medicine, environmental protection, trade, and others. Without them, it would be impossible to make informed decisions or to develop effective products, structures, and processes.

Modern measuring instruments can measure very precisely, technologies and methods are also very advanced, but the factor of human error or lack of competence can nullify all modern achievements. Adequate competence plays an important role in all metrology fields that ensures that measurements are accurate and reliable to protect consumers and businesses. Lack of metrological competency, or the ability to correctly and consistently measure physical quantities, can lead to a variety of risks.

The demand for skilled metrology personnel is expected to grow in the coming years, as businesses increasingly rely on accurate and reliable measurements to ensure the quality of their products and services.

1. Introduction

This review will present the importance of metrology personnel competencies to the quality of measurements. The requirements for metrology personnel in different countries vary depending on the specific jurisdiction. However, some general qualifications are typically required for metrology personnel, regardless of location. These qualifications may include: a bachelor's degree; experience; proficiency in the use of metrology instruments; and knowledge of standards. International Document OIML D 14 Training and qualification of legal metrology personnel [1] is the legal basis for training and qualification. According to OIML D 14, the review of metrological situation and model of metrology personnel education in Lithuania and other Baltic States was presented in IMEKO joint symposium in Madeira in 2014 [2]. Analysis of personnel education system showed that countries which destroyed their system some years ago now confront with the difficulties when new personnel do not have basis and knowledge of metrology terms, uncertainty evaluation even basic tasks as verification performance.

Metrologists are responsible for developing, maintaining, and applying measurement standards to ensure the accuracy and reliability of measurements. Metrology personnel are required to have a wide range of skills and competencies to perform their jobs effectively. In addition to these core competencies, metrology personnel may also need to have specialized skills in a particular area of metrology (for example, mass, pressure, volume, temperature, dimension, chemical, variety of electrical measurements, etc.). Metrology personnel can develop their skills through a variety of means, including formal or non-formal education, on-the-job training, participating in conferences, symposia or training organised by professional organizations.

Under the impact of digitalization, the twofold task of keeping up with the technological progress of measuring instruments and of finding

the best blend of digital methods for the training of legal metrology officers appeared [3]. Metrology personnel play a critical role in ensuring the accuracy and reliability of measurements in a variety of fields. In today's world, many measurements are done electronically. Metrology personnel ensure the integrity of this data by implementing data management systems and procedures to prevent errors and manipulation. By ensuring the accuracy and reliability of measurements, metrology personnel contribute to consumer protection (accurate measurements ensure consumers get what they pay for and that products meet safety standards), fair trade (consistent measurements across different countries facilitate fair trade by ensuring everyone is using the same frame of reference), scientific advancement (reliable measurements are essential for scientific research and development), safety and efficiency (accurate measurements are crucial in many industries to ensure safety and efficiency).

2. Importance of competent personnel

Competent personnel are more than just skilled employees. The importance of various abilities and necessary skills allows to perform tasks effectively. This translates to less work, smaller errors, and a smoother workflow, ultimately boosting productivity. The competence leads to problem-solving and innovation, i.e. the problems can be identified and solved independently; critical thinking contributes to innovation. This adaptability is crucial in today's dynamic environment. Competent personnel can analyse data, choose options, and make right decisions that align with the goals. Building a team of competent personnel requires a multi-pronged approach:

- Effective recruitment. Focusing on skills, experience, and the ability to learn ensures a good fit for the role.

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- Continuous learning. The training allows employees to stay up-to-date and develop new skills.
- Performance management. Regular feedback help identify areas for improvement and acknowledge accomplishments.

Fig. 1 presents the summarised importance of competent personnel where the main activities for the fluent task solving are highlighted.

2.1. Metrology personnel competencies

Metrology personnel competencies can be divided into the categories as it is shown in Fig. 2. Technical skills include things like understanding the principles of measurement, being able to calibrate instruments, and knowing how to use statistical methods to assess measurement uncertainty. Problem-solving skills lets to identify and solve problems related to measurements. Metrologists need to be able to think critically, analyse data, and come up with creative solutions. Communication skills help to communicate with clients, colleagues, and other stakeholders. This skill enables to explain technical concepts in a clear and concise way also to listen to and understand the needs of others.

Metrology personnel competencies are essential for ensuring the quality of measurements, which is important for a variety of reasons, including:

- Ensuring safety (for example, the safety of products, processes or environment). The health or environment protection are especially sensitive fields. Responsible control of the performed measurements and used measuring instruments are of high importance from the consumer protection viewpoint. Continuous and sustainable attitude with reducing negative impacts in these fields leads to more qualitative understanding of importance of education and competence maintenance of responsible personnel.
- Enhancing product quality (for example, it directly impacts customer satisfaction, possible financial losses, reliability). Competent personnel understand the principles of different measurement techniques and the limitations of instruments. This allows to choose the right tools and methods to obtain the most accurate measurements that are critical for ensuring that products meet design specifications and functions. Competent personnel can identify deviations from specifications early on, allowing for corrective actions and preventing defective products from reaching the final stage. The expertise ensures that measuring instruments used on the production line are accurate and reliable, further contributing to product quality.

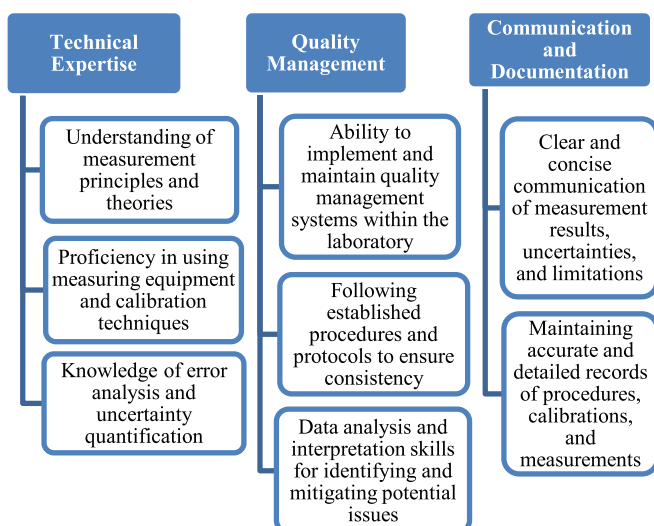


Fig. 1. Importance of competent personnel.

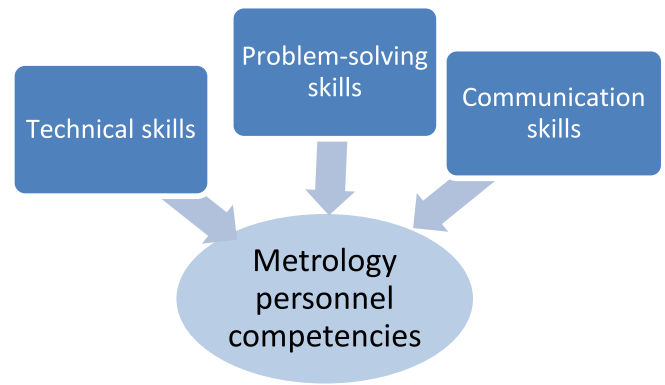


Fig. 2. The categories of metrology personnel competencies.

- Enhancing competitiveness (accurate measurements can give companies a competitive advantage). As it was discussed in previous paragraph, competent personnel ensure accurate measurements throughout the production process, leading to fewer defects, higher quality products, and increased customer satisfaction. This translates to a competitive edge in the marketplace.
- Compliance with regulations (some industries are regulated by government agencies; accurate measurements are the integral part).

The importance of metrology personnel competencies cannot be overstated. Accurate measurements are essential for a variety of reasons, and competent metrology personnel are essential for ensuring that these measurements are made. By investing in the development of metrology personnel competencies, companies can improve the quality of their products, enhance their competitiveness, and comply with regulations.

2.2. Developing personnel competencies

Despite the fact that the competence of metrology personnel is extremely important for the quality and reliability of measurements, but in many cases the opportunities for qualification improvement depend on the company's approach.

There are a number of ways to develop metrology personnel competencies. These include:

- Formal education. There are a number of universities and colleges that offer degree programs in metrology. These programs provide students with the theoretical and practical knowledge.
- On-the-job training. Many employers offer on-the-job training programs for metrology personnel. These programs provide employees with the opportunity to learn how to use specific metrology equipment and techniques.
- Professional development. There are a number of professional organizations that offer training and certification programs for metrology personnel. These programs help professionals stay up-to-date on the latest developments and improve their skills.

2.2.1. Personnel training and development across countries

Despite the OIML document D-14 provisions, the specific requirements and structure for gaining metrology qualification across the European Union (EU) can vary depending on the country. Mandatory vs. optional certification can differ depending on the specific area of metrology. Some countries prioritize international standards and advanced techniques, while others focus on practical skills or mandatory areas. Quite often special programs are offered by national metrology institutes (NMIs) or universities with metrology departments. Private training providers might also offer relevant courses. National accreditation bodies often play a key role in overseeing metrology practices.

Performed comparison of legal metrology personnel training systems in some EU and other countries analysis is given in the Table 1.

Due to variations within countries, this review serves as a starting point for further and more detail research. It's difficult to say definitively which countries have no requirements for metrology personnel. Almost all countries will have some level of training or competency expected, even if not formally mandated. However, based on the information gathered, some countries tend to have a stronger focus on basic principles and on-the-job learning, with less emphasis on formal qualifications or certifications.

The EU has a single market for goods, and ensuring consistent and accurate measurements throughout the market is crucial. Even with a common framework, EU member states have some flexibility in implementing legal metrology regulations. This can lead to minor variations in specific requirements.

In any case well-trained metrology personnel is needful for accurate measurements, innovation, and a strong global economy. Efforts towards international collaboration and harmonization could ensure consistent training standards across borders.

2.2.2. Main common strategies for metrology personnel training

With the purpose to decide about the need of competency development the following additional considerations should be performed: needs assessment, budget allocation, performance measurement. Main strategies for metrology personnel competency development are described in Table 2.

By implementing a combination of these strategies, organizations can ensure their metrology personnel possess the necessary knowledge, skills, and abilities to perform their jobs effectively and deliver accurate and reliable measurements.

2.3. Reliable measurements

Reliable measurements are the foundation of accurate and trustworthy data in many fields. They ensure the consistency and dependability of the information obtained. Reliable measurements are vital in science and engineering. Scientists use measurements to collect data, test hypotheses, and develop theories. If measurements are inaccurate or unreliable, the results of scientific research can be flawed. This can lead to incorrect conclusions and wasted time and resources. Engineers use measurements to design products, construct buildings, and develop manufacturing processes. If measurements are unreliable, the resulting products, structures, and processes can be unsafe or ineffective. This can

Table 1 Comparison of legal metrology personnel training systems.

Country	Training Focus	Training Programs	Regulation & Standardization	Resources
Lithuania	International standards, accreditation	Universities, Private Providers, National Metrology Institute	National & International (BIPM)	Lithuanian Metrology Inspectorate (LMI), KTU Institute of Metrology website
Germany (PTB)	Advanced techniques, quality management	National Metrology Institute (PTB), Universities, Private Providers	National & International (BIPM)	PTB website, DAkkS website
France (LNE)	Industry-specific applications	National Metrology Institute (LNE), Universities, Private Providers	National & International (BIPM)	LNE website, COFRAC website
Italy (ACCREDIA)	Mandatory for specific areas	National Accreditation Body (ACCREDIA) (Primary), Universities (Secondary)	National & International (BIPM)	ACCREDIA website, INRIM website
Spain (ENAC)	Practical skills	National Accreditation Body (ENAC) (Primary), Universities (Secondary)	National & International (BIPM)	ENAC website
USA (NIST)	Strong emphasis on scientific principles	National Metrology Institute (NIST), Universities, Private Providers	National (NIST) & International (ILAC)	National Institute of Standards and Technology (NIST) website
UK (UKAS)	Accreditation, competency	National Accreditation Body (UKAS), Universities, Private Providers	National (UKAS) & International (ILAC)	United Kingdom Accreditation Service (UKAS) website
Australia (NATA)	Strong industry collaboration	National Accreditation Body (NATA), Universities, Industry Associations	National (NATA) & International (ILAC)	National Association of Testing Authorities (NATA) website
Japan (NMIJ)	Advanced research and development	National Metrology Institute (NMIJ), Universities, Private Providers	National (NMIJ) & International (ILAC)	National Metrology Institute of Japan (NMIJ) website
India (BIS)	Basic principles and compliance	National Standards Body (BIS) (Primary), Universities (Secondary)	National (BIS)	Bureau of Indian Standards (BIS) website

Table 2 Main strategies for metrology personnel competency development.

Strategy	Description	Benefits
Formal Training Courses	Courses or workshops offered by national institutes, professional organizations, or universities.	<ul style="list-style-type: none"> - Structured learning environment. - Fundamental and advanced metrology concepts. - Recognized certifications.
On-the-Job Training	Experience under the guidance of metrology professionals.	<ul style="list-style-type: none"> - Practical skills using measurement equipment and performing calibrations. - Knowledge transfer. - Adapted to specific workplace and equipment.
Technical Skills Development	Training programs focused on specific technical skills (uncertainty analysis, or specific measurement technique).	<ul style="list-style-type: none"> - Improved accuracy and reliability of measurements. - Current stay with evolving technologies. - Problem-solving skills.
Soft Skills Development	Training programs on communication, report writing, data analysis, and quality assurance practices.	<ul style="list-style-type: none"> - Communication of technical information. - Documentation and results procedures. - Adherence to quality standards.
Industry Participation	Participation in conferences, workshops, and professional organizations.	<ul style="list-style-type: none"> - Communication with experts. - Staying updated on industry trends and best practices. - Knowledge sharing.
Self-Directed Learning	Self-learning through online resources, technical publications, and professional journals.	<ul style="list-style-type: none"> - Continuous learning and development. - Focused learning on specific areas of interest. - Flexibility for learning at one's own pace.

lead to accidents, injuries, and financial losses. The other field where the reliable measurements are of high importance is healthcare and medicine. Doctors use measurements to diagnose patients, monitor their progress, and prescribe treatments. If measurements are inaccurate or unreliable, patients may receive incorrect diagnoses or treatments. This can lead to serious health problems. Reliable measurements are also important in other fields, such as quality control, environmental monitoring, business, law, and government. Regardless of application, reliable measurements should cover the following characteristics that are presented in Fig. 3. Listed key characteristics help to ensure the same or

very close result each time if you measure the same thing multiple times, under the same conditions.

Evaluation of factors affecting reliability of measurements depends on the field of interest but in most common attitude they can be as follows:

- Instrument calibration (or verification). Regular metrological supervision of measuring instruments is crucial to ensure their accuracy and minimize systematic errors.
- Measurement technique. Following proper measurement technique and procedure consistently is important to minimize human error and ensure reliable results.
- Environmental conditions. The factors, such as temperature, humidity, dustiness, or vibration, can affect measurements. Controlling these factors or accounting for their influence is essential for reliability.
- Measurand. If the “object” that is measured is naturally variable, it can be harder to get a perfectly consistent reading.
- Operator qualification. Competent and well-trained personnel is one of the most important factors for reliable results.

In summary, without accurate, consistent, and unbiased measurements that are performed by competent personnel, it would be impossible to make informed decisions or to develop effective products, structures, and processes.

3. Conclusions

This study reveals the importance of the competence of metrology personnel in ensuring the quality of measurements. Personnel training and development in metrology varies significantly across countries. Developed nations often have robust programs with international standards and certifications, while developing nations might rely on on-the-job training. These variations can impact trade, consumer protection, and technological advancement. Competent personnel contribute to:

1. Reduced measurement uncertainty and/or reliable measurements. Personnel with appropriate skills understand the principles of measurement, proper use of equipment, and how to minimize systematic and random errors. In this way the uncertainty is lower and data reliability higher.
2. Enhanced traceability. Personnel with expertise is able to maintain the traceability with internationally recognized standards. Their knowledge ensures measurements can be definitively linked to a well-defined reference; the measurements data can be comparable.
3. Quality assurance cannot be implemented without quality management systems. Their understanding enables controlled measurement environment, promoting continuous improvement of best practices in laboratories.
4. Increased customer confidence. Customers who have a high degree of certainty regarding the metrology personnel qualification, can trust in the validity of the measurements performed.

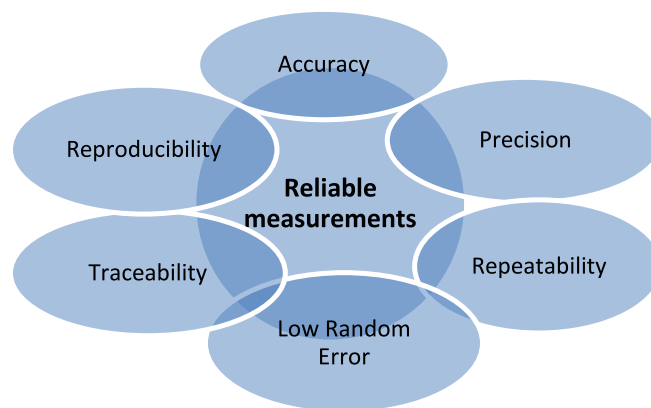


Fig. 3. Key characteristics of reliable measurements.

In conclusion, the performed study emphasizes the importance of competency development for metrology personnel. Increasing digitalization and automation forms the need of a highly skilled workforce. Investing in the training and development of metrology personnel is an investment in our future, guaranteeing the quality and reliability of measurements that underpin scientific discovery, industrial processes, and societal progress.

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