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EDUCATION AND COMPETENCY EVALUATION SYSTEM OF METROLOGY PRACTITIONERS IN LITHUANIA

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Abstract: metrology practitioners in Lithuania are taught, trained following the program adopted in 1995 and improved in 2000. A huge amount of information related to various aspects of the program has been collected since the beginning. Continuous analysis of the program directly supports its future improvement and long-term goals.

Keywords: metrology**,** occupational education, competency evaluation.

1. INTRODUCTION

After Lithuania's separation from the Soviet Union the centralized system of metrological supply collapsed. The system had a strict hierarchy, in which all metrology activities were regulated by a set of non-voluntary state standards (GOST). All measurement (measuring instruments were submitted to the mandatory) applied without exception the mandatory State or departamental verification. Most of metrology practitioners (services in metrology oriented offices as well as working in industrial areas) could perform only elementary metrological actions– verification according to standard methodologies. Great amount of human resources were needed for such tasks, although without strict requirements to the level of qualification. Metrology practitioners were trained for a very narrow specialization; they were able to check just specific measurement means, for example, scales or manometers, etc. Metrologists were prepared in short training courses, where they learned to verify of specific measurement instruments (such an action as calibration was not known nor applied).

The heritage of the soviet system was the following:

1) Methodological and normative basis created in central soviet Metrology Institutes, was based on different principles than in the Western European countries.

2) There was no scientific institution to solve the scientific problems of metrology and to coordinate them.

3) The basis of means was incoherent, low-level, without traceability to higher-level standards (previously standards were verified against higher level USSR standards).

4) Low qualification of metrologists. The major challenge was a lack of metrologists ready to adopt practice of the western countries and to start working in the market economy.

Change in economic system and a move to the market oriented economy resulted in a deep shock both to industry and metrology. Under such conditions the national Metrological Supervision System (MSS), which was radically different from the previous one, was being created. MSS had to be harmonized with the analogous EU systems both in the areas of legal and industrial metrology. In order to reach full political and economical integration of Lithuania into the European Union, it was necessary to aim at regulations, valid in the EU in the area of legal acts, to use all resources existing in the country for the structure and technical subsystem.

During the transitional stage specific knowledge was obtained primarily from Danish, German and Finnish experts by a means of short courses, workshops and seminars. This facilitated to learn about approaches in the other countries. A complex project called „National program of metrological supervision. Project of system development" was successfully carried out by Lithuanian scientific institutions together with the metrology services in Lithuania in 1995-1997. Strategy of development of national MSS was drawn, and model of MSS established taking into account available economic and technical potentialk and use of intellectual resources.

In order to establish a national metrological assurance system in the Republic of Lithuania (transition period from Soviet to European system) it was necessary to create a new complex program for qualification and training of metrology practitioners. The goal of the program was to match (to harmonize) competence of local practitioners with that of foreign ones. As a result, a programme called „Complex program of education, training and re-qualification metrology practitioners" was developed and launched in 1995 aiming at preparation of different level specialists. Subsequently, it was improved in 2000.

The qualification and training is set up in a modular structure, which allows a country to arrange tailor-made training programs according to the preconditions and specific needs (qualification on demand) [1].

2. MODEL OF EDUCATION AND COMPETENCY EVALUATION SYSTEM

2.1. Analysis of process

Education and competency evaluation system of metrology practitioners was created basing on the general provisions of establishment of qualification system. All qualifications in qualification system are divided according to the levels defined by the complexity and nature of performed works. All interested partners – training executors, experts-representatives of employers and employees - participate in determining qualification levels. Every level corresponds to a certain competence, i.e. an ability to perform a certain task. A competence and its nature describe a qualification. An education program is formed in order to achieve a competence. This system is flexible, because it allows quick and simple preparation of qualifications (which are traditionally understood as professions or specialisation), but it is not easy to implement it. Firstly, qualification preparation principles have to be determined.

The first stage of this process is the design of qualifications, preparation of qualification standards. It consists of preparation of professional standards, formulation of qualification levels and structures as well as of preparation of education programs.

A process of system [2] of metrology practitioners education and qualification development are presented in figure 1.

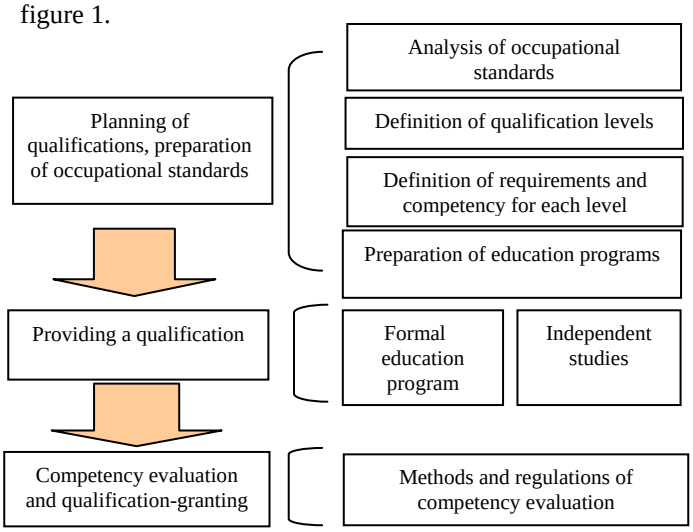


Fig.1. Process of qualification-granting level

The contents of a professional standard encompass description of professional activity, characteristic to that profession, workplace, means, conditions and environment; work relations and ties; main personal qualities necessary for a particular profession.

An education program consists of professional activity fields, competencies, and limits of competencies, education aims, subjects, and competence evaluation. A competence is a demonstration of a successful performance of a certain task, using one's own knowledge and skills. The limits of competence are different variants of competence display. Education aims are the description of students' knowledge and skills, necessary to gain a particular competence. Competence evaluation is assessment references what knowledge and skills have to be evaluated. Prepared programs are presented for evaluation and validation. Program evaluation order is regulated by the description of vocational training program preparation and validation order. This description is approved by the Minister of Education and Science of the Republic of Lithuania.

Master and Engineer metrologist study programs are a part of general university study programs' system. The mechanism of study program evaluation has been created. These programs are reviewed and evaluated by experts. The methodology of study program evaluation is based on the experience of many European countries.

Continuous study programs for metrologists are agreed with Kaunas University of Technology. These programs are approved by the State Metrology Service, an institution, which is authorized by the Government to develop and implement metrology policy in Lithuania.

Studies of metrology can be both formal and informal. The state does not regulate the content of these study programs and certificates, issued afterwards. Formal studies are studies, where a person gets a certificate, recognized by the state. Formal study programs are included in the State Register of Study and Training Programs, therefore, organizations, enterprises and educational institutions, willing to provide education according to these programs, have to get a license. Formal studies in the metrology field encompass study programs, which provide a professional qualification of a "metrologist". A person, who completes the training, is granted a certificate, recognized by the state, confirming professional qualification. The duration of these study programs varies from 1 week to 2 years.

An important stage of qualification preparation process is the creation of competence evaluation and qualification recognition system. It means that competence evaluation methods and regulations have to be projected and described.

2.2. Qualification levels.

University studies and continuous education (non-university studies) are organized to prepare specialists of metrology and measurement sciences in Lithuania. (Figure 2) Dash line indicates „Engineering metrology" study, which was cancelled after implementation of binary high education system in Lithuania. This type of study was replaced by a study for Master of applied metrology.

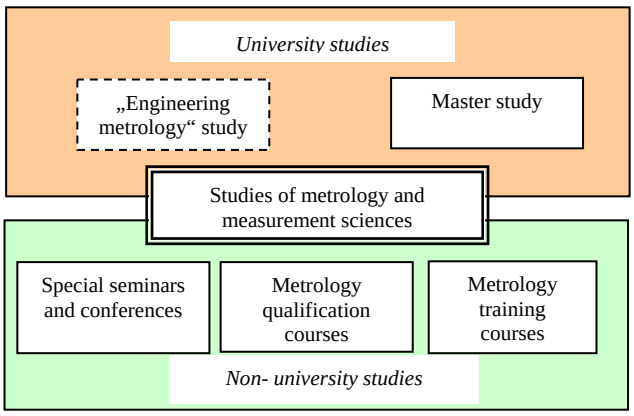


Fig.2. Ways of metrology and measurement sciences study

University education is more exhaustive, wider and more fundamental. Students acquire methodological skills of

solving complex problems as well as consolidate special knowledge in the field of science they study participating in scientific activities. Communication among scientists and students in different science fields provides persons with university education additional universal knowledge, which is necessary for taking responsible decisions. Continuous training studies encompass: metrologists' preparation, qualification development and re-qualification courses. A student is prepared for a specific qualification in a short time. He gets theoretical background and skills necessary for professional activity. At work he acquires practical skills. A great focus in these study programs is on linking theoretical knowledge with practice. Therefore not only theoretical background, but also the experience in the professional field is necessary for a lecturer.

Aspects to describe each level of qualification:

- main competency [3]: functional competency (skills), cognitive competency (knowledge), general competency (other features, abilities);
- educational institution for providing qualification;
- training forms to gain qualification;
- minimal required educational background;
- career opportunities in metrology.

Prospective four occupational qualification levels [4] are shown in figure 3.

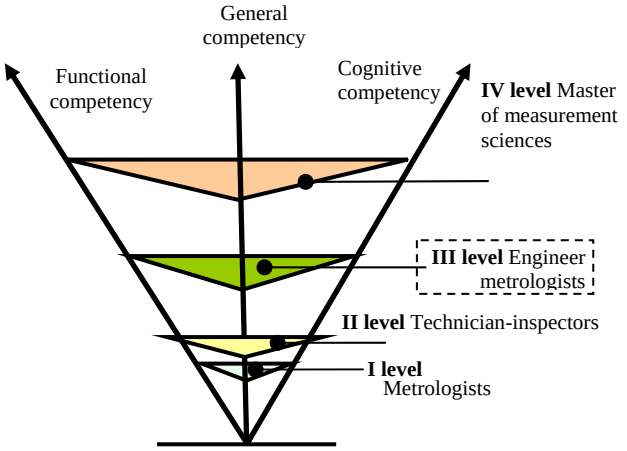


Fig.3. Metrology qualification levels

Metrologist is a person who has a technical university or technical college diploma (or more than one year work experience in metrology) and has finished metrology qualification courses. He/She is able to carry out equipment control, maintenance and calibration of measuring instruments in a factory or a laboratory.

Technician-inspector is a person who has a technical university or technical college diploma (or more than one year work experience in metrology), has completed metrology qualification courses and passed the state qualification exam. Technician-inspector has a similar legal status, is responsible for the execution of various tasks defined within the framework of the application of laws and regulations in legal metrology. He/She is able to apply verification and calibration methods to verify or calibrate different measuring instruments. Their qualification allows him/her to perform metrological maintenance of measuring instruments. Technician-inspector with such qualification can work in national institutions while implementing OIML Recommendations, standards or carrying out general evaluation of measurement uncertainties.

Engineer-metrologist is a person who has a technical university diploma and has finished a one-year study in applied metrology and successfully coped with a diploma work. After introduction of binary high education system it ceased to exist.

Master is a person who has a technical university diploma and has finished one and a half or two years extended studies concerning modules of measuring instruments and metrology, acquired research skills and was awarded a master's degree in metrology. Masters perform highly specified tasks in science, industry or laboratories for type approval. The possession of this degree is a prerequisite of entry to a doctor's studies in the field of metrology.

A first model of education and competency evaluation system for metrology practitioners (Ph.D. is cutted out) is presented in figure 4.

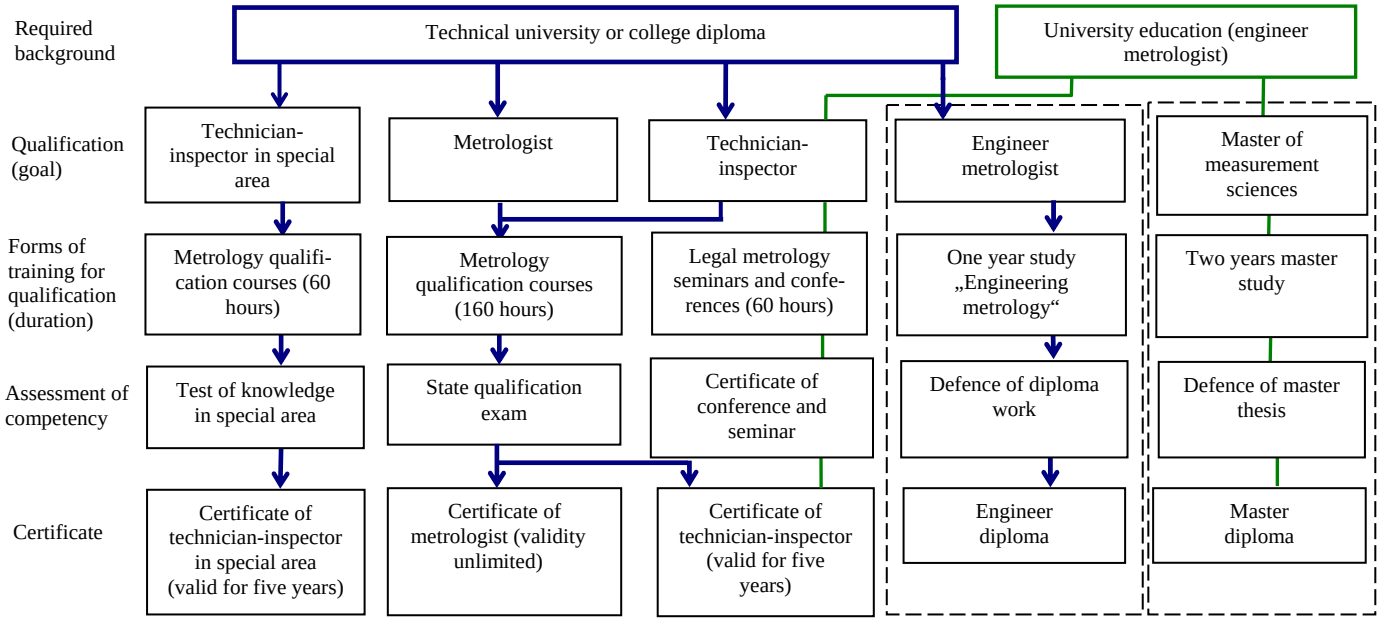


Fig.4. A former model of education and competency evaluation system for metrology practitioners

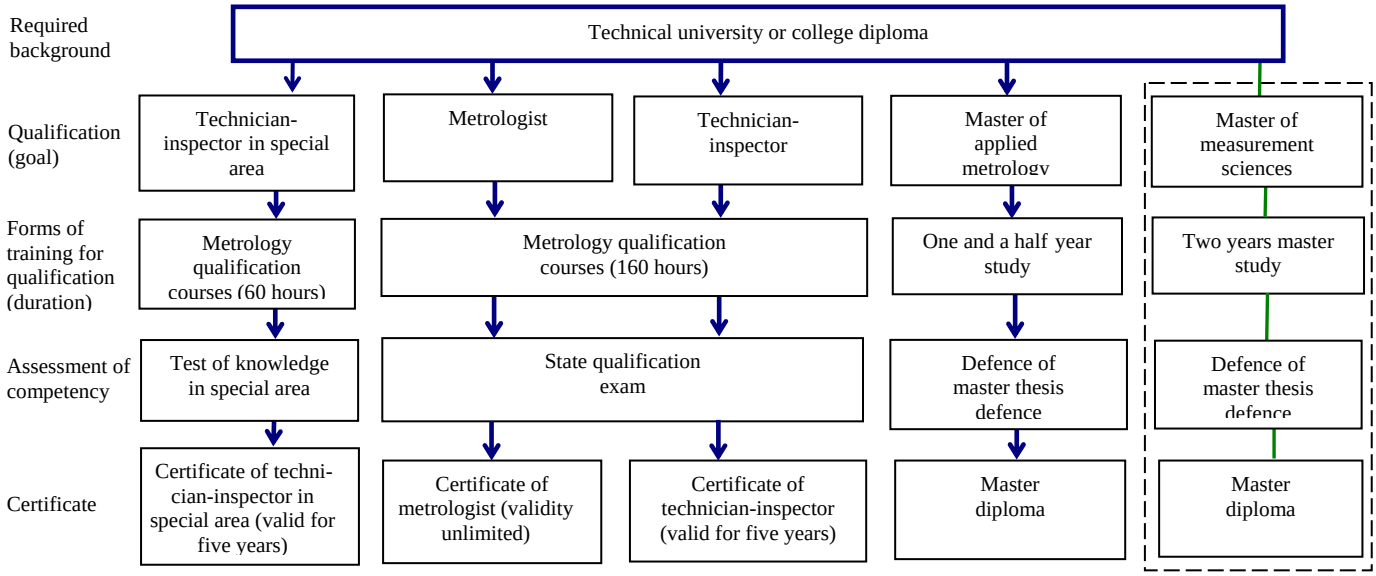


Fig.5. An improved model of education and competency evaluation system for metrology practitioners

The initial training module used to qualification of engineer metrologist. Today this qualification is replaced with a qualification of master of applied metrology (figure 5). The primary requirement for metrology qualification levels: technical university or college diploma. Knowledge in mathematics and physics are strongly needed in the field of measurements and metrology. Students of non-technical universities, colleges or vocational schools do not have sufficient knowledge in these fields. It is possible to acquire the same qualification in different ways, as the forms of training for qualification and assessment of competence vary. Persons with technical university or college education can become a metrologist or a technician-inspector. There is an exception foreseen for those who have practical skills but do not have a diploma in technical sciences. Persons, having technical university education, can acquire a qualification of master‘s degree of applied metrology or measurement sciences (following studies according to the scientific program of the university).

A model of re-education and re-grant for metrology practitioners is presented in figure 6. Metrologists can choose workshops and conferences, organized in the field of metrology in order to develop their qualification. The proof of participation in such conferences is a certificate. Re-education and re-grant of a technician-inspector is especially important. Only people with a certificate of a technician-inspector may verify measurement means, assigned to legal metrology. In order to obtain this certificate, people have to participate in the metrologist training courses every five years. Before 2008 the validity duration of a technician-inspector certificate was just three years. The reason of validity duration change is a stable and clear (compared to the years 1995 – 2000) politics of metrology as well as scientific, legal and administrative activity in the issues of metrology.

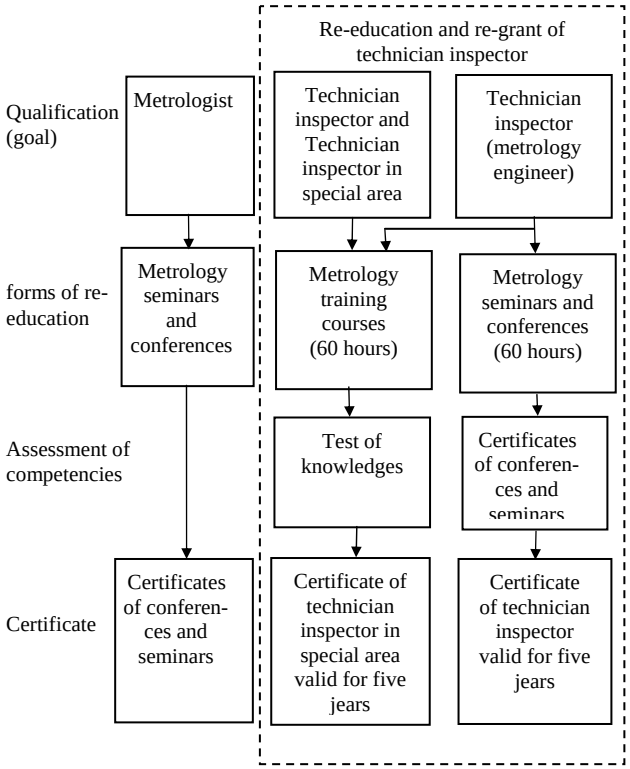


Fig.6. Model of re-education and re-grant for metrology practitioner

2.3. Competency evaluation and qualification grant.

To evaluate and confirm a competency of the system it is necessary to prepare provision for it.

State-administered institution establishes requirements for competency evaluating bodies. Metrology Institute of the Kaunas University of Technology is a body authorized to evaluate competence in metrology. Kaunas University of Technology and Vilnius Gediminas Technical University are bodies that arrange studies in this field. Manufacturers and suppliers of measuring instruments, educational and other institutions organize workshops and conferences for

persons who work in the field associated with measurements. Metrology Institute arranges seminars, conferences, metrology qualification and training courses.

Educational and training program is developed to meet the requirements of international standards [1]. The content of education programs depends on:

- constantly changing and newly issued law acts, development of measuring devices and measurement methods;
- distribution of theoretical and practical knowledge;
- coordination of opinions and attitudes of students**,** employees and research staffs (questionnaires, responses);
- innovations in educational process (methodical material, knowledge tests).

The main purpose of the training program is to provide all course members with the opportunity to improve knowledge and skills, i.e. to obtain a particular competency in the field of electric or non-electric measurement or in other specific area.

Three main metrologist training programs can be distinguished. One of them is for obtaining a qualification of a metrologist or a technician-inspector. The second one is for getting a metrologist-engineer's qualification and the third training program is for acquiring a Master of measurement sciences qualification. (Figure 7). The duration of disciplines/subjects is chosen according to the volume of study materials in each case.

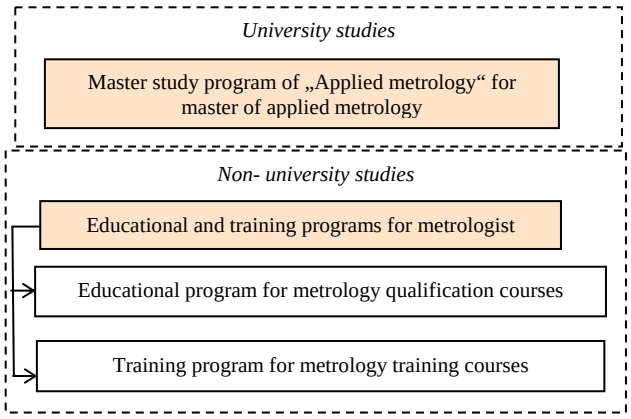


Fig.7. Programs for the attainment of metrology qualification

Table 1. Modules of educational program stadies for master of applied metrology

Modules	Term, credits
Metrology and measurement theory	4
Measurement of physical quantities	6
Computerisation of measurements, computer practice*	4
Verification and calibration of measuring instruments*	2
Legal metrology	2
Design, production and supervision of measuring instruments*	2
Research work	20
Master thesis	20

*Alternatives: „Measurement transducer and sensors“- 2cr., **„**Electronics elements“- 4cr. Module „Metrology and measurement theory“ is mandatory for those who undertook studies in non-electrical field.

The duration of studies according to the program "Applied metrology" (qualification – Master in applied metrology) in day time studies is three semesters (total number of credits is 60). A credit corresponds to 40 hours of study time, including the time for classes and individual preparation.

The study modules are shown in Table 1. The goal of the studies is to get ready to work on its own in development of complex experiment methods in practical research, measuring instruments as well as to prepare for PhD studies in the field. Bachelor in technical sciences is a must to be allowed to study there. Bachelor specialised in non-electrical measurements has to take a course on basics of electronics. Two modules can be chosen from existing alternatives

Educational program for metrology qualification courses is split into 4 specialized fields: non-electrical measurements, electrical measurements, physical - chemical measurements, and radiation measurements. When necessary a number of specializations can be increased. The duration of these courses is 160 hours. 50 hours are devoted for the measurement means and methods of quantities topical for a certain speciality (non-electrical: mass, pressure, volume, density, temperature, geometrical measures; electrical: resistance, voltage, power, inductivity, frequency, physical-chemical concentration of substance quantity; radiation: radiation power flow, its activity, absorbed dose. The other general disciplines are given in table 2. Qualification courses with duration of 60 hours are provided for verifiers of particular measuring instruments (tachographs). The program of the course is, in principle, a reduced aforementioned program. After passing a state exam, a technician-inspector qualification certificate of a prescribed form is issued. If the exam is not passed a person is granted a certificate of a metrologist. The validity of a metrologist certificate is unlimited.

Table 2. General disciplines of educational program for metrology qualification courses

Disciplines	Term, hours
Traceability system and general metrology principles	18
Verification and calibration of measuring instruments	12
Conformity assessment system	10
Computer use in metrology practice	26
Practice, laboratories	44
Measurement means and methods of quantities topical for a certain speciality	50

The duration of the training program for metrology training courses is 60 hours. The titles of disciplines and their duration are given in table 3.

Table 3. Disciplines of training program for for metrology training courses

Disciplines	Term, hours
Improvement of metrology development, practice problems	6
Traceability system and measurement standards	4
National metrological infrastructures and surveillance of measuring instruments	8
National regulations and standards	8
Importance and determination of errors and measuring uncertainties calculation	8
Conformity assessment system. Principles of accreditation and certification“	8
Statistics and probabilities	8
Practice, laboratories	10

After passing a course credit test (accounting for theoretical course and practical tasks) a certificate of a technician inspector in a special area is issued or the

validation of a certificate of a technician-inspector is continued.

Number of staff of the State Metrology Service, National Accreditation Bureau, Universities, and accredited laboratories deliver lectures for students. Practical training sessions are carried out in premises of verification or calibration laboratories.

The content of training programs and conditions of the final exam are documented transparently. The content and duration of lessons are documented as well.

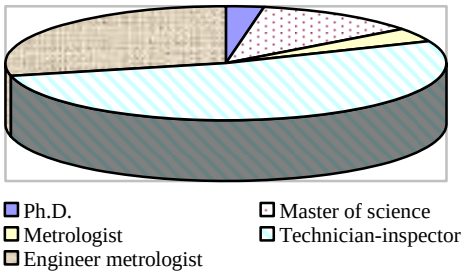
A person, who has been possessed competences of adequate level (figure 3), passed successfully qualification exam or test, defended diploma or thesis for a Master degree, obtains a Certified Specialist qualification. S/he is supposed to have sufficient amount of knowledge and competences, meets the requirements for a technician-inspector. Therefore, they can acquire a qualification of a technician-inspector without taking the state qualification exam. S/he can gain new knowledge for their qualification development by participating in various trainings, courses, seminars, workshops and conferences, related to metrology and measurements. The certificates of seminars, workshops, conferences and other trainings provide an opportunity to identify, analyze, name completed trainings. The critical principles for recognition of non-formal and individual learning are the following:

- only university-level learning can be assessed;
- proofs to substantiate such type of learning are necessary (i.e. purposefully selected various documents: certificates, recommendation letters, etc., which can prove that a person who provided them has not only got many years of experience, but also certain knowledge, which is adequate to the requirements of the qualification degree).

During training studies State Qualification Board is established for evaluation of qualification exam. State Qualification Board consists of five members. Two of them are appointed by an employer (s/he is a head of the Board). University employees (professors, associated professors, research staff, etc.) are appointed to the board accordingly.

3. METROLOGY EDUCATION AND RE-EDUCATION IN LITHUANIA AT PRESENT

An average of persons, who are trained according to this program in accordance with the calculations over the past 5 years, is 110 technician-inspectors (70% of all students are staff of manufacturers), 8 metrologists, 60 Engineer metrologists (total amount of Engineer metrologists since 2000), 25 Masters of Science and 6 Ph.D. (figure 8).



8. Persons, who were trained according to this program during five years

60 students have graduated from the University and defended Metrology engineer diplomas. Most of them were employees of state companies-metrology centers. These bodies are appointed to verify measuring instruments in legal metrology as well as they are accredited for calibration and/or testing of measuring instruments and pre-packages.

Technician-inspectors, who need an extension of a certificate validity, and manufacturer staff and manufacturer assignees constitute the main part of students. Manufacturer staff constitutes approximately 70% of all students of qualification courses. Changes of manufacturer's point of view concerning the quality of production and skills of staff influence these circumstances.

Students participate in national and international research projects and programs in measurement engineering successfully**.**

Scientists from University work together with State Metrology service personnel. State Metrology service is authorized by Government of the Republic of Lithuania to form metrology policy in Lithuania, establish and maintain state measurement standards, co-ordinate uniformity of measurements, organize and carry out scientific, legal and administrative activities in metrology field. Scientists cooperate with manufacturers, tests or calibration laboratories, state companies-metrology centers on a regular basis. Seminars and conferences on relevant subjects associated with measurement engineering and metrology are organized on the issue. Certain conferences are organised on a yearly basis. a conference "Topical Problems of Legal Metrology" was held by KTU Metrology Institute In April 2008. The heads of state organizations with responsibilities in metrology (State Metrology Service, Lithuanian Metrology Inspectorate, National Accreditation Bureau, representatives of metology centers, industrial enterprises, universities participated in it. The following topical themes were discussed: documents regulating legal metrology and their implementation; the accreditation practice of verification laboratories-assigned institutions, prevention of Metrology law violations in Lithuania and its practical tasks; realisation of legal metrology acts in the practice of law and order. Such conferences have a huge practical use, as they decrease the gap between theory and practice (real life).

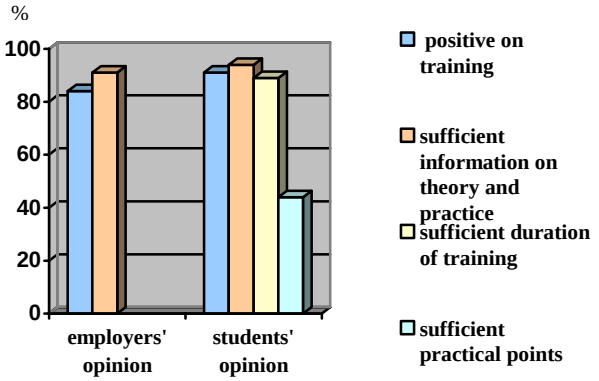
The qualification system of metrology specialists enables to assign a specific training program to the corresponding level of requirements. An employer knows that the owner of a certificate is able to perform certain work. According to the data of surveys, employers prefer employees with the following skills:

- a suitable professional competence;
- communication skills;
- responsibility;
- creativity;
- foreign language skills;
- computer literacy.

Students demand the newest information in the field of metrology, innovations in the way knowledge is provided and in the final examinations.

It is not easy to react to customers' and consumers' requirements in a proper way. Local and benevolent initiatives are not sufficient for improvement of training programs. Systematic training changes, which encompass all training elements – from training program creation to the granting of qualification - are necessary.

The reactions of employers and students are an important criterion in assessment of the correspondence of the training content to their expectations. Opinions and evaluation by employers and students who completed the continuous training courses are presented in figure 9.



9. Employers' and students' opinions and evaluation

Study programs, organisation of courses and evaluation are regularly improved in constant consultations with the employers taking into account new needs arising.

4. CONCLUSIONS

Education and competency evaluation system of metrology practitioner allowed to pass fluently from Soviet to European system, assisted for various institutions to assess a level of competency in metrology. Educational institutions will benefit from the system in creation educational programs to prepare metrology practitioners.

The aim of initial education is to prepare a person for a work. The aim of continuous training is to keep him/her at work. This principle is used for the organisation of metrologist education and re-education studies. For the offer of suitable labour force in metrology field is limited, continuous training is becoming an especially important element of work. Such studies allow to renew labour force.

To update the system new tendencies of science, industry, nanotechnologies, development of chemical metrology, it has to be considered.

This system has to be incorporated into general national qualification system that is established in Lithuania. It has to contribute personal advantage in vocational training, to increase qualification conformity with the national economics demands.

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