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Measures of improvement MUVoT, a Blended Learning course on the topic of Measurement Uncertainty for advanced Vocational Training

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Abstract

In verifying the tolerance specification and identifying the zone of conformity of a particular component an adequate determination of the task-related measurement uncertainty relevant to the utilized measurement method is required, in accordance with part one of the standard “Geometrical Product Specifications” as well as with the “Guide to the Expression of Uncertainty in Measurement”. Although, measurement uncertainty is a central subject in the field of metrology and is certainly considered to be of significant importance, there is still a perceived lack of knowledge on the subject within employees in the field of quality management and industrial metrology. They are often neither familiar with procedures for the determination of measurement uncertainty nor with the interpretation and analysis of measurement results as well as economic consequences of decisions taken at the level of conformity. Furthermore, in times of increasing globalization relating to products, processes and development, in which ever more producers cooperate with institutes and companies from all over the world, there is a strong demand and need for a transnational vocational training on the topic of measurement uncertainty.

For that reason, in the European project MUVoT (“Blended Learning course on measurement uncertainty for advanced vocational training” - Leonardo da Vinci – Transfer of Innovation 2011-1-PL1-LEO05-19870), a course for advanced vocational training on the topic of measurement uncertainty was established in cooperation with seven institutes from six European countries to provide an internationally harmonized education programme and thus guarantee a better quality of products through the training of metrologists. The training offer is based on a Blended Learning concept, combining self-dependent learning via a web-based eLearning platform and class teaching in face-to-face workshops. On the one hand, this allows the adaptation to individual knowledge and skills by self-controlled learning of abstract contents. On the other hand, the exercises enable the practical application of typical methods, which are generally considered as quite complex by many employees, and thus assure correct understanding. Furthermore, class teaching in manageable groups of participants offers the possibility of adaption to individual training needs. The integration of vocational training into a job-based application is facilitated, so that the idea of Lifelong Learning is promoted in new fields of application. Taking into consideration, that the target group of this training consists of participants with a very inhomogeneous qualification, including foremen, skilled workers, technicians and engineers, the course contents are provided in a modular structure with preparatory, basic and advanced chapters.

By performing pilot courses at each project partner, the course content has been thoroughly tested and feedback has been sought and given allowing for a policy of continuous improvement. This article describes the results of these evaluations and the targeted improvements of the content and overall concept considering the identified competence requirements and needs of the participants.

Keywords: Vocational Training; Measuremnt Uncertainty; International Harmonization; Blended Learning; Sustainable Quality Assurance

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1. Introduction

Creating a solid foundation in accordance with ISO 9001 [1], the skills and knowledge of employees form the basic structure that enables sustainable quality management. Thereby, an adequate education and qualification of employees ensure a required level of quality is maintained, reduce rejected parts and consequently save an immense amount of money. In metrology, an operator's lack of knowledge may leads to erroneous or unreliable measurement results thus leading to subsequent incorrect decisions. To decide if a measured part is suitable or not, it has to be examined to establish if the measurement result lies within the required tolerance zone, taking into consideration the measurement uncertainty in accordance to ISO 14253-1 [2]. In the international vocabulary of metrology (VIM) measurement uncertainty is defined as a "non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurement, based on the information used" [3]. To determine this uncertainty, all influences affecting the measuring system must be taken into consideration. Calculating the propagation of uncertainty, a profound level of knowledge of mathematical expertise is required including a working knowledge of statistics and curve sketching. Although the GUM – "Guide to the expression of measurement uncertainty" [4] - provides a comprehensive guide comprising methods and procedures to determine the measurement uncertainty, it is quite difficult for many employees to understand, largely due to the technical nature of the presentation of the information and also due to the fact that they do not necessarily possess the required level of background knowledge. To close this gap and enable operators to achieve the required level of knowledge thus minimizing the risk of unusable measurements caused by inadequate estimation of measurement uncertainty a targeted education is required. Based on evaluations performed in a previous project called "SAM-EMU - Statistical Analysis of Measurement Data for the Evaluation of Measurement Uncertainty" [5], focusing on students at universities, a great demand for vocational training on this topic for employees in industry was identified. Therefore, the internationally harmonized training course MUVoT – "Blended Learning Course on Measurement Uncertainty for Advanced Vocational Training" (Leonardo da Vinci – Transfer of Innovation 2011-1-PL1-LEO05-19870) –focusing on the specific requirements of industrial employees in manufacturing metrology has been developed to educate metrologists and thus achieve the goal of a higher level of and sustainable quality management.

2. Development at an European level

In times of increasing globalization and intensive efforts toward greater international standardization to facilitate cooperation across borders and between institutes and companies from all over the world, there is a strong demand and need for a transnational vocational training on the topic of measurement uncertainty. A first step toward this goal has been made by developing MUVoT at an European level with seven institutes from six countries.

Table 1: Partners of the MUVoT project

Partner institution	Country
University of Bielsko-Biala, Laboratory of Metrology	Poland
Friedrich-Alexander-Universität Erlangen-Nürnberg, Institute of Manufacturing Metrology	Germany
University of Huddersfield, Centre for Precision Technologies	Great Britain
University of Padova, Department of Innovation in Mechanics and Management	Italy
Technical University of Cluj-Napoca	Romania
Interstaatliche Hochschule für Technik Buchs NTB	Switzerland
International Foundation for World Class Manufacturing	Poland

Prior to developing the learning materials, an user needs analysis of the target group was conducted to identify core required and desired competences. This was achieved through the establishment of a target group oriented design, focusing on the specific training needs and previous knowledge of potential participants in conjunction with assessment of the inhomogeneous nature of previous education of the target group, which included skilled workers, technicians and engineers. To enable an internationally harmonized training design, the course content has been originally developed in English by the experts of their respective institutions. After checking and matching the learning materials by all of the partners, the content was translated into national languages, because a large number of employees in industry in various EU countries may not be familiar or comfortable with English as teaching language.

However, the development in a common language ensures that the same content exists in all national versions and facilitates updates concerning changes in standards or methods as well as adaptions to specific competences.

3. Course content and improvements

Taking into account the evaluations performed to identify the targeted needs of the potential participants, the course content was developed.

Course development was split between the experts of six institutes according to their experience and expertise to optimally and adequately produce course content. The learning material comprises nine chapters which include both core knowledge and advanced expertise, characterized as optional, core, practical and advanced elements to optimally address participants' needs.

Starting with chapter 1 “Basic statistics”, a general grounding in ideas of methods in statistics and stochastic including analysis of correlation and regression as well as statistical estimations is given. This knowledge provides a solid foundation for the following chapters. The first module was initially designed as an optional element refreshing the statistical knowledge of the participant. As a result of the performance of three pilot courses it was found that generally the statistical background knowledge was much lower than expected, so the decision was taken that this should become a core module.

In chapter 2 “General methodology of uncertainty evaluation”, methods and procedures according to the GUM are succinctly summarized in a clear and easily understandable manner. Although the GUM provides a comprehensive guide, it is written in specific professional terminology and can be considered to be quite impenetrable to employees with a less specialized level of background knowledge. Evaluation reports from the pilot courses highlighted a lack of knowledge concerning the practical application of curve sketching. It was therefore decided that a greater level of mathematical revision content would be included as part of the introductory workshop.

Chapters 3 to 5 are chiefly concerned with the most important measurement devices in dimensional metrology including conventional manual measuring devices, coordinate measurement machines and tactile surface roughness measurement devices and their associated uncertainty budgets. In these three modules, diverse calculations of uncertainties are shown based on the knowledge given in module 1 and 2. The need to constantly refresh this material in light of the adoption of new standards is a significant challenge.

Table 2: Content of eLearning materials

Topic of the module		Category
1	Basic statistics – Basics of descriptive statistics and stochastic – Analysis of correlation and regression – Statistical estimation and testing	optional element
2	General methodology of uncertainty evaluation – Uncertainty budgeting according to GUM – Overview of approaches to uncertainty calculation – Documentation and interpretation of measurement uncertainty	core element
3	Uncertainty of conventional measurements – Introduction to conventional measurements and main error sources – Uncertainty budgets for typical examples of conventional measurements (gauge blocks, calliper, micrometre, dial gauges)	core element
4	Uncertainty of coordinate measurements – Introduction to Coordinate Metrology – Evaluation of uncertainty using calibrated workpieces – Evaluation of uncertainty using computer simulation	core element
5	Uncertainty in surface roughness measurement – Introduction to Surface Metrology – Evaluation of uncertainty using ANOVA method – Evaluation of uncertainty using computer simulation	core element
6	Uncertainty in calibration – Requirements of a Calibration Laboratory – Calibration monitoring	practical element
7	Measurement systems analysis (MSA) – Aim and Framework of Measurement Systems Analysis – Characterising properties of measurement systems	practical element
8	Economics in manufacturing metrology – Quantification of inspection process costs and value-adding – Economic evaluation of investments in metrology	practical element
9	Uncertainty in case of multivariate measurands – Introduction to advanced modelling of measurements – Uncertainty analysis with correlation calculation	advanced element

Modules 6 to 8 consist of a number of practical elements detailing uncertainty in calibration and the related fields of measurement system analysis and economics in manufacturing metrology. These chapters are constructed so as to provide advice on practical implementation. are constructed so as to provide advice on practical implementation..

Finally chapter 9 “Uncertainty in case of multivariate measurands” was developed as an advanced module to deepen the mathematical knowledge concerning the calculation of uncertainties through correlations. It is envisaged that this particular module would be of interest to a small number of highly specialised individuals.

The eLearning materials are developed in HTML, which enables the integration of multimedia content and facilitates navigation through use of a menu bar (Fig. 1).

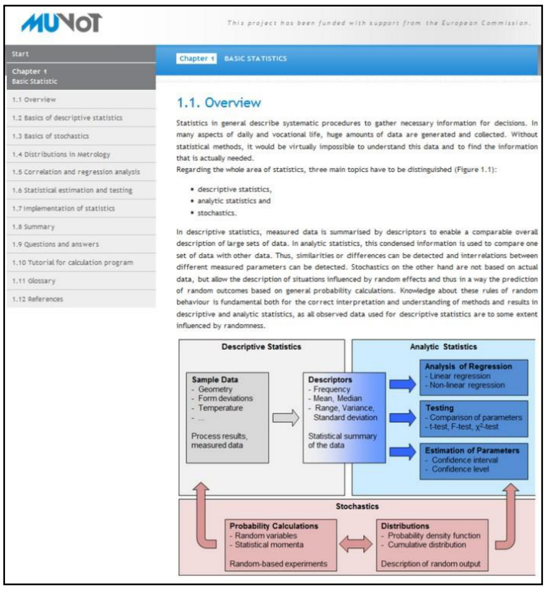

Fig. 1: Screenshot of chapter 1

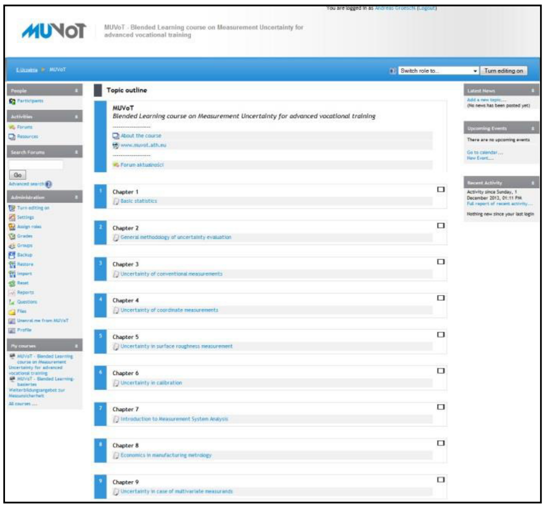

Fig. 2: Screenshot of MOODLE-platform

Feedback received in other web-based courses carried out at the partner institutions has shown that a large number of participants still desire some form of printed version of the course content. The HTML format allows for a simple conversion of the content to other file formats, such as a printable PDF which are personalised and copy protected.

The eLearning chapters are provided on a web-based MOODLE-platform, including forums, chats and online questionnaires (Fig. 2).

Additional information about the project and forthcoming courses can be found on the official homepage: http://www.muvot.ath.eu (Fig. 3).

Fig. 3: Screenshot of MUVoT-homepage

4. Performance of pilot courses

In order to put the developed learning materials to the test, three pilot courses were performed in each institution. Within these employees from industry were invited to attend for free and detailed feedback was requested. From the feedback evaluations were executed to identify any shortcomings and to generally provide a steer to improve the course materials. The course schedule is based on the alternation of eLearning phases and face-to-face workshops (Fig.4). Using this blended learning concept combines the advantages of traditional class teaching and eLearning whilst the disadvantages of both methodologies are compensated for by the application of the other. One of the major problems of purely web-based courses, that has been previously identified is the absence of social interaction between tutors and participants. This has been largely overcome by the fact that during the eLearning phases, there is ongoing communication between tutors and participants via mails, Skype, tele-conference and forums. Similarly a purely class-based approach to teaching requires a lot of time on the part of both the instructor and the student and this demand generally is thought to be inconsistent with the idea of vocational training in the workplace. In MUVoT, a structure made up of a blend of three face-to-face workshops and two self-contained learning phases has been developed. It is thought that this will enable a professional level of tutoring support and allow for the adaption to individual learning behavior and speed.

Each of the pilot courses had a duration of 6 weeks. This provided a sufficiently flexible timeframe for the implementation of improvements and analysis of the evaluation results. One of the outcomes of the pilots was that the demands on the participants were such that the length of the course should be extended to 10 weeks.

Before starting the first learning phase, a workshop was implemented to introduce the learning concept, registration process and use of the eLearning platform. The outcome of the pilot feedback has been that in future this workshop will also contain elements of mathematical revision relating to the necessary areas of background knowledge required (statistics and curve sketching). In the mid-point of the course, a major workshop session lasting for a period dependent on level of study (usually 2 days) is enacted which consists of applied lab-based exercises.

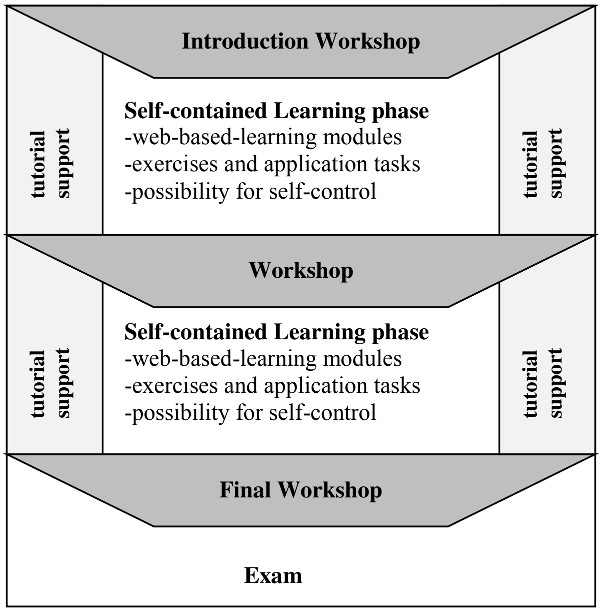

Fig 4: Course schedule of MUVoT

Upon examination of this workshop it is envisaged that further individualized training needs can be identified and as such remedial action may be taken.

The course is summatively assessed by the sitting of a 60 minute written examination. A pass mark of 50/100 is set to provide evidence of the acquired knowledge, to enhance learning and to increase the participants' motivation.

5. Evaluation of course content

Importance was given at the outset to individual user needs and requirements with attention focused on the level of user satisfaction with the structure and content of the training course. In a bid to guarantee that the course fulfilled the need for a holistic approach to the subject, some of the course evaluation material was worded to garner a response to this end. An anonymized online evaluation form, using the eValue platform, has been constructed to collect elicited responses going forward.

The evaluation form used in connection with the pilot courses, was firstly developed as a paper copy and was limited to a double-sided A4 sheet to enable an efficient and adequate response. Questions are grouped into four sections; "General course flow", "Face-to-face Workshop", "Tutor" and "Miscellaneous". A combination of multiple-choice and open ended questions allows for both the generation of comparable statistics and also the monitoring of individual participant's needs.

In the first section "General course flow", there are some general questions on course content, comprehensibility and design, including adequate use of illustrations and animations. In summary the pilots determined that the overall quality was predominantly rated with "good" and "very good".

Section 2 deals with questions on the "Face-to-face Workshop" and contains multiple-choice questions on fulfillment of expectations and the comprehensibility of the workshop content as well as a free text question about additional topics to be addressed in the workshop in future.

Through this exercise it was established, that there is a great demand for workshop content relating to methods in optical surface roughness measurement. As soon as standards on this topic are available, it is clear that they should be integrated in the course by developing an additional chapter.

In section 3 of the evaluation, questions relating to the tutors are asked, concerning motivation and engagement as well as the responsiveness to questions and needs of participants. In the pilot evaluations these questions were universally rated as very positive. This is a gratifying and necessary result as it is a key tenet that a pleasant relationship between tutors and participants is built and maintained.

Section 4 of the evaluation "Miscellaneous" contains questions which ask for suggestions on improvements as well as a request to state which modules are of particular use. The outcome of the pilot evaluation here suggested that some participants would like more 'real' exercises in which the uncertainty of real measurement devices is obtained. However, this conflicts directly with another suggestion that the given examples be more simplified. Overall, the evaluation suggests that the course content is and that an appropriate compromise between real practical exercises and simplified examples is reached. Furthermore, the participants rated the course performed as a blended learning concept very positively as was also the case for the relationship between tutors and participants and the possibility to respond to individual needs and requirements.

6. Evaluation of the project

To ensure sustainable success an evaluation of the MUVoT project and development is of equal importance to the evaluation of the course content. Therefore, an online evaluation was performed by using an eValue system provided by Institute of Manufacturing Metrology of Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU). Especially developed for eLearning based courses, the eValue model (Fig. 5) is adapted from the EFQM model [6]. Developed and published by *European Foundation of Quality Management*, the EFQM model allows evaluation of an organization by nine categories and for comparison with other organizations by a calculated indicator. Analyzing the results, improvement measures are derived to enhance the performance of the organization. [7]

Similar to EFQM model, the evaluation model eValue contains nine categories divided into enablers and results. Each category is weighted by a specific score which is representing the maximum value for the category. Thus, project management, user satisfaction and learning transfer exert a high influence to total value of 1000 points. Involving diverse groups of people adequately, three different roles of evaluators are defined: [6]

- "Enablers" covers the developers of the course including project members, project managers and superiors. The enablers are evaluating the development process of the course.
- "Experts" are evaluating the content, didactics and presentation of the course materials.
- "Costumers" are course participants evaluating the user satisfaction and possibility to transfer and apply theoretic knowledge to practical tasks.
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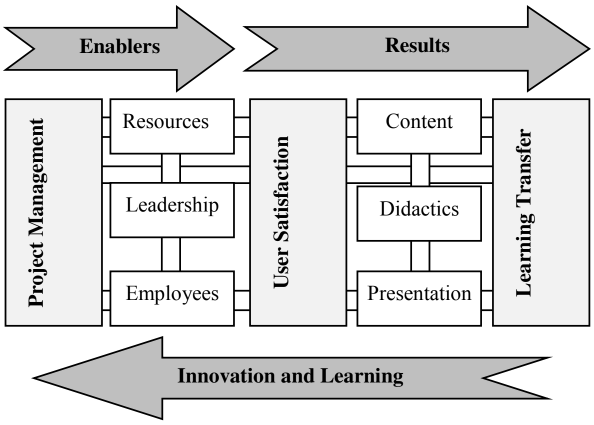

Fig 5: eValue-model

The evaluation system eValue is realized by a web-based platform to guarantee an unrestricted access for each project member and course participant. The integrated reporting tool permits the analysis of the collected data. In subsequent courses, the evaluation will be performed by using this platform, running the risk of less response but enabling a facilitated analysis and collection of data.

Acknowledgements

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