XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

TRAINING IN COORDINATE METROLOGY
EUKOM: MADE IN EUROPE – OPEN TO THE WORLD

Albert Weckenmann [1], *Sebastian Beetz* [2]

Chair Quality Management and Manufacturing Metrology, University Erlangen-Nuremberg, Germany
[1] albert.weckenmann@qfm.uni-erlangen.de
[2] sebastian.beetz@qfm.uni-erlangen.de

Abstract: Due to the flexibility and precision of coordinate metrology operators have to possess comprehensive knowledge. Since in most countries no vocational education exists, they have to gain these competencies otherwise. The concept EUKOM defines European-wide harmonized training for impartment of metrological competence and of machine-independent basic knowledge in coordinate metrology.

Keywords: coordinate metrology, vocational education and training, blended learning

1. INITIAL SITUATION

The precondition for the success of a company is the efficient application of methods and strategies of quality management, which allows manufacturing of high-quality products. Decisions in quality management are mainly based on knowledge about the manufactured workpieces, which are gained by measurements. Therefore, it is essential to achieve accurate and precise measurement results in order to prevent that inappropriate measures are taken based on erroneous assumptions.

Since tolerances for manufacturing continuously become smaller, whereas complexity of workpieces increases capable measuring techniques have to be applied in order to achieve measurement results with ample precision. Due to their universality and flexibility, the application of coordinate measuring machines (CMM) constantly boom. In addition to measurement of lengths in three dimensions, they are applied to determine geometrical deviations on workpieces or to digitize unknown surfaces. In particular CMM's are used for measurement tasks with high demands on accuracy.

1.1. Influences on the measurement result

Also measurement results of CMM's are affected by deviations and uncertainties. Deviations in coordinate metrology are caused by the operator, environment, workpiece and CMM. It can be assumed that the influencing factors operator – environment – machine have a relative importance of approximately 100:10:1 in causing deviations [1].

Nowadays, influence of CMM's on the measurement uncertainty is downright very small, due to the highly sophisticated machine technology, to the back tracing of CMM's to national and international standards and to the application of powerful compensation software. In addition, influences of the workpiece and the environment can be minimized by appropriate measures, e.g. by temperature soaking of the workpiece, by consideration of the expected form deviations of the workpiece surface or by elimination of environmental influences in an air-conditioned measurement room.

In contrast, there are currently no sufficient possibilities to reduce the operator's influence. This influence is also caused by motivation and applied elaborateness, but mainly by operator's skills and experiences. For measurements with a CMM comprehensive and multidisciplinary knowledge is required. In order to reduce the dependence of the measurement results upon the operator and thus to advance the accuracy of results it is necessary to provide the required knowledge to the operator in such way that it can be applied during the performance of the measurement.

1.2 Current training situation

Since in most countries, even in Germany, no occupational profile "Metrologist" and in consequence no vocational education exists in manufacturing metrology, employees have to gain the competencies required for competent performance of measurements during job-accompanying measures. This knowledge acquisition can happen while participation in attendance-based training courses or by self-conducted learning using books or Internet as well as during the exchange of experiences with competent colleagues.

Manufacturer-dependent training is in most cases not fulfilling the requirements of a comprehensive education. In these trainings, the main focus is on the operation of proprietary hardware and software. But generally no fundamentals in metrology or metrological competencies are taught.

In order to improve this situation, several national activities are under development or already exist, which offer manufacturer-independent training in coordinate metrology. Such training is only available in some European countries.

In Germany, the AUKOM project has been launched to promote machine-independent training for CMM operators [2]. Nowadays, the most important CMM manufacturers

belong to the association AUKOM e.V., which has been founded in continuation of the project. In other European countries also training activities are available, e.g. CMM Club (Italy), INSACAST (France) and BEVAN (UK).

These concepts vary in their focused aspects of coordinate metrology, but only refer to attendance-based training. The restricting condition of this training form is that the learners have to come together at a certain place and time. The training courses are not available to the learners "just in time". Moreover, the absence of the learners from their workplace causes high cost for the employers.

In a European perspective, training in coordinate metrology is inhomogeneous and not comparable. But, employees and employers would profit from a unique and innovative European training standard in this area of expertise.

2. TRAINING CONCEPT "EUKOM"

Within the framework the Leonardo da Vinci programme the EUKOM project has been submitted with the objective to consolidate and harmonize vocational training activities in coordinate metrology in Europe. A consortium of seven European partners coordinated by Chair QFM, consisting of experts in coordinate metrology and for learning psychology and pedagogy, conducted the project.

The main objective of the project was the development of a comprehensive European training concept for coordinate metrology that included the following partial intentions: the definition of a European-wide comparable and high-quality level of training in coordinate metrology as well as the development of Europe-wide uniform training materials. Within the project, an innovative learning arrangement for coordinate metrology was developed taking the realization of new learning strategies into account.

2.1. Curriculum

In order to investigate the demands for training in coordinate metrology a user needs analysis (UNA) with the target group has been performed. The investigation has pointed out that the flexibility of CMMs and their wide application field requires a high level of training with a well-founded basis. Based on the results of this UNA, the target qualifications in the training concept have been set up and the expected competences of the users have been defined. Considering the needs of the users and the experience of training activities the curriculum was developed.

Furthermore the results have confirmed that in industry a hierarchical task and responsibility sharing in the area of coordinate metrology exists. The training concept considers these requirements and consists of the hierarchical training levels considering the target groups CMM-User, CMM-Operator and CMM-Expert (table 1). This structure is similar to existing concepts [2, 3]. The determined learning contents of the training levels have been subdivided in several training modules regarding the covered topics (table 2).

Table 1. Target qualifications in coordinate metrology

	The *CMM-User* is aimed at ordinary users. They shall be capable to perform common measurement tasks, where an appropriate programme including the intended measuring sequences is available. Their duties will be restricted to preparing and initiating measurement procedures at the CMM.
	The *CMM-Operator* is aimed at advanced users. They shall be capable to define measurement tasks by means of technical drawings, create measuring programs independently and evaluate the measurement results considering influences, which may cause deviations. Besides, they shall be capable to monitor CMM and equipment.
	The *CMM-Expert* is aimed at professional users. They shall be capable of planning, programming and optimising measuring sequences for any complex measurement and of finally estimating the measurement uncertainty. In addition, they shall monitor and control measurements, other operators and their qualification. For this purpose they shall be capable of utilising quality management methods.

The depth and width of the module's content increase from level to level and bases on the content of the prior level. This hierarchical composition meets the expected competences of the participants after finalizing one of the

Table 2. Target qualifications in coordinate metrology

Level 1: CMM-User	Level 2: CMM-Operator	Level 3: CMM-Expert
1-01 Measurands and units in coordinate metrology	2-01 Overview – complete measuring sequence	3-01 Expert knowledge – Geometry
1-02 Location in plane	2-02 Overview – Geometry	3-02 Basics – Manufacturing
1-03 Location in space	2-03 Tolerances of size	3-03 Basics – CAD
1-04 Geometric features	2-04 Geometrical tolerances	3-04 Expert knowl. – Datums
1-05 Geometric links	2-05 Measurement strategy	3-05 Expert knowl. – Geometrical tolerances
1-06 Fundamentals of metrology and testing	2-06 Probing strategy	3-06 Optimized measuring sequence
1-07 Basic elements of a CMM	2-07 CNC programming	3-07 Expert knowl. – CNC programming
1-08 Types of CMM	2-08 Evaluation	3-08 Digital filtering and evaluation
1-09 Preparation of measurements at CMM	2-09 Influences on measurement result	3-09 Stochastic
1-10 Stylus configuration and qualification	2-10 Documentation	3-10 Evaluation of measurement uncertainty
1-11 Measurements with CMM	2-11 Use of statistical parameters	3-11 Quality management
1-12 Evaluation of measurements a. statistics	2-12 Statistic process control	3-12 Monitoring of CMM
1-13 Accuracy	2-13 Basics – Inspection equipm. monitoring	3-13 Quality costs
1-14 Basics – Quality management	2-14 Basics – Quality management	3-14 Digitizing of freeform surfaces
1-15 Self-organised learning	2-15 Non contact coordinate metrology	3-15 Good Coord. Measurement Practice
		3-16 Measurement room management

levels [4]. Main objective of the training is to enable participants to fulfill the requirements by their scope of duties.

Beside the technical content, an additional module has been integrated into the curriculum. The module "Self-organized learning" is targeted to the participants, in order to enable them for learning in an e-learning system.

Furthermore, all modules have been detailed with the description of the learning aims and contents as well as of the expected competences of the learners afterwards [4]. The didactical approach has been defined for each module in regards to both the contents to be delivered in the online course and during the face-to-face workshop.

2.2. Training methodology

The change of working conditions, caused by a value change in society and business, massively impacts the needs of employees regarding their vocational education and training. Learning accompanying to the working process becomes more and more important. Thus, EUKOM was targeted to develop a methodology for supporting workplace-embedded learning.

For this purpose, learning with a web-based e-learning platform opens possibilities to deliver the learning contents at the workplace, assuming that there is access to a computer and Internet. In such a platform learners can gain knowledge by working through different learning modules, organize their learning process and communicate to other learners or to tutors via implemented tools (fig. 1). But contents of e-learning are focused on declarative knowledge, since this kind of knowledge is describable or illustratable by figures. And solely learning on the computer is not satisfying from a didactical point of view. Thus, a combination of learning units, which can be performed self-controlled and of face-to-face workshops seemed to be reasonable. This blended learning approach allows participants free timing and structuring of their own learning behavior at the computer based elements.

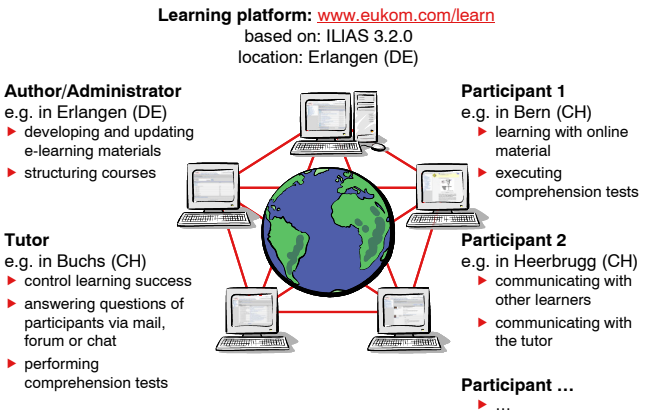

Figure 1. Activities at the learning platform on example of the second Swiss pilot training course

The additional face-to-face workshops are an important part of the training and allow the learner to deepen the knowledge by performing practical exercises and to get a better understanding of the delivered knowledge. The advantage of this approach is that the learning content can always be delivered in the most favorable way. In addition, the tutored e-learning courses enable a user centered-approach.

Furthermore, this methodology enables learners to participate in the EUKOM training in form of in-service training, which is widely accepted by learners and employers. It reduces the period of absence to a necessary minimum.

2.3. Training structure

Based on the methodology design and on findings of the UNA the learning arrangement for the training concept EUKOM was designed that applies a sequence of attendance-based learning phases and self-directed learning phases for the training structure of each level (fig. 2).

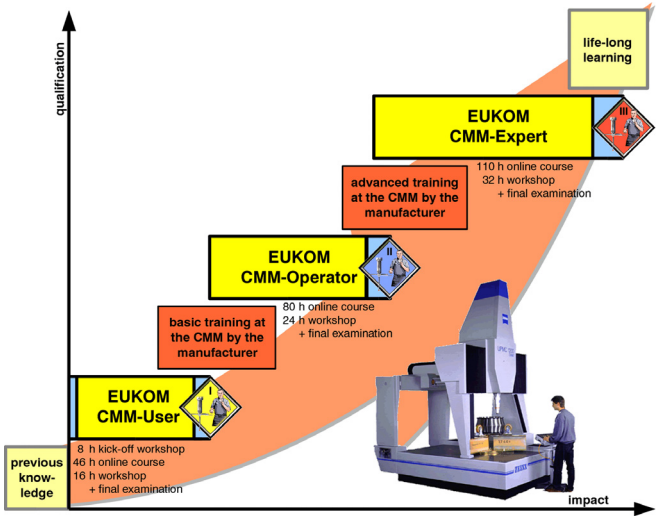

Figure 2. Three-stage hierarchical training structure for coordinate metrology according to the EUKOM concept

The training level CMM-User starts with a kick-off seminar, where the learners will be introduced into the course schedule and into the handling of the learning platform. This seminar will take approx. 1 working day. Afterwards a self-directed learning phase on the e-learning platform follows. During this phase all contents of a training level are presented online to the learners. The time effort for the self-directed acquisition of the training contents will be approx. 46 hours, which takes approx. 6 weeks provided that the learners spent 8 hours per week on learning. After the self-directed learning phase follows a workshop, where the recently studied contents are consolidated and practically applied. This workshop takes approx. 2 working days and is conducted by one of the training providers as well as the kick-off seminar. The training level CMM-User concludes with a final examination, wherein the attendees have to prove their gained competencies.

The training levels CMM-Operator and CMM-Expert are similarly organized. Only the kick-off seminar is left out, since the attendees have already been introduced. Certainly, the time effort for the self-directed learning phases (10 weeks and 14 weeks) and for the workshops (3 days and 4 days) of these levels is different due to the wider scope and to the higher intellectual level.

The training concept doesn't assert claims to completeness. According to the idea of lifelong learning the educa-

tion coordinate metrology should not be regarded as completed, when finishing the qualification of CMM-Expert. Therefore, possibilities for further qualification are permanently pointed out to the learners, also for manufacturer-specific training at the CMM.

The training contents of the level CMM-User is designed in such a comprehension that no professional prerequisites have to be possessed by the learners. Only skills in handling a computer and the Internet are requested. Before entering a next level it is recommended that the attendees should apply and consolidate their gained knowledge during a practice period with duration of a half year.

After successful passing the final examination of a training level the attendees will get an acknowledged certificate with the degree CMM-User, CMM-Operator or CMM-Expert, which will verify the gained qualification. This certificate should enable the attendees to satisfactorily show their competences in an easy way.

2.4. Pilot training courses

In order to verify the prepared training concept pilot training courses for level 1 and 2 have been performed in United Kingdom, Austria, Switzerland, Poland, Romania and Germany with members of the target group. Over 70 participants attended the pilot training courses of first level.

For these pilot courses the consortium has developed multimedia training content (fig. 3). These materials were provided via the learning platform www.eukom.com, which is running under ILIAS (fig. 4). This platform provides the learners various communication facilities beside the training materials. Using these facilities the participants can create learning groups or discussion forums and can contact other learners or their tutors.

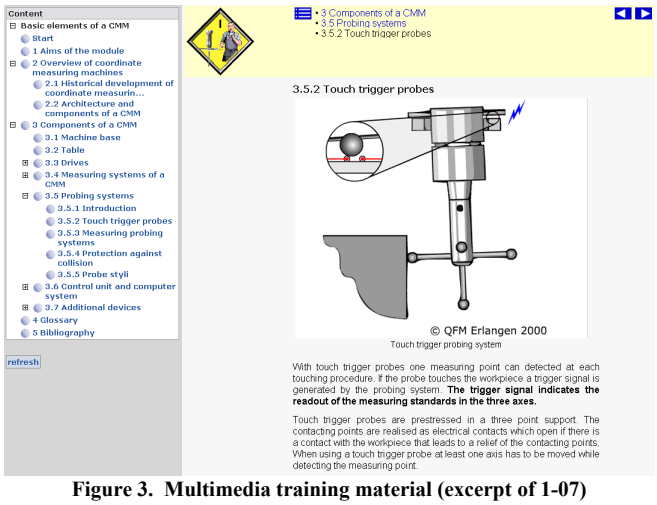

Figure 3. Multimedia training material (excerpt of 1-07)

Since English was the common language for authoring the training material, the materials have subsequently been translated into the native languages of the partners. Now, the training materials of level and 2 are available in English, German, Polish and Romanian. Further language versions, e.g. Italian, are already in preparation. The training material for the third level is currently under development.

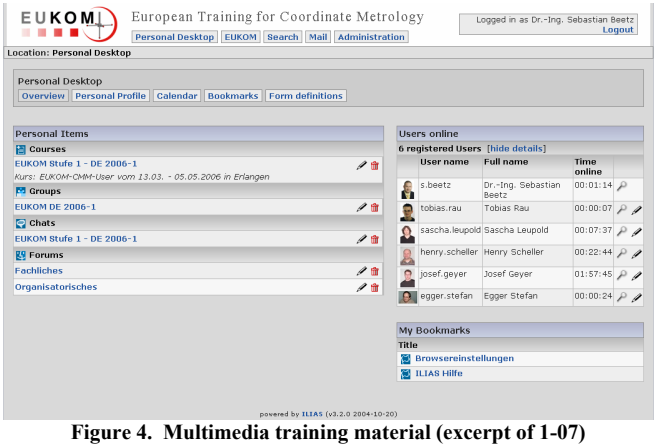

Figure 4. Multimedia training material (excerpt of 1-07)

The positive results of the pilot training courses encouraged the consortium in their ambition to go on with the ideas of the project EUKOM and to optimize the project results with the aim to offer the content in a commercial way.

3. CONTINUATION OF EUKOM

As part of its valorization strategy the EUKOM consortium formed on October 21st, 2005 in Buchs (CH) the non commercial association "CMTRAIN – Training for Coordinate Metrology e.V.". CMTRAIN's headquarters are in Erlangen (DE) [10].

According to its objectives CMTRAIN provides the legal successor to EUKOM and represents the EUKOM consortium in cooperation with other European training providers. For this purpose, CMTRAIN will continue the development of high-quality training materials for coordinate metrology and manufacturing metrology in general.

Besides these ideal objectives CMTRAIN provides training materials for training courses on the learning platform. The contents, currently comprising the multi-language version of modules of level 1 and 2, will be regularly extended and updated. Further take up of the training concept in Europe and Worldwide will necessitate further translation of the materials into other languages with French, Spanish and Portuguese being priorities.

All bodies and individual members are welcome. But only corporate members will be able to offer EUKOM training, provided that they have tutors trained and acknowledged by CMTRAIN.

Already for the constitutional meeting representatives of Italy and Denmark have joined CMTRAIN with the intent to provide training in their countries. Also further parties from other continents have already shown their interest.

4. CONCLUSION

With the European training concept EUKOM the basis for a manufacturer-independent and comprehensive training in coordinate metrology has been set up. The EUKOM concept considers the various needs for training in Europe and supports a work accompanying learning by the application of an innovative blended learning strategy. This strategy

combines web-based e-learning courses with attendance-based workshops to a powerful approach.

The already conducted pilot training courses in several European countries acknowledge the developed curriculum, methodology and training structure. The participants are highly satisfied with both the training materials and the learning platform. Only slight difficulties in platform handling had to be resolved during the next time.

The formal end of the funded part of the EUKOM project will not prove to be the end of the project as plans are in place to carry on with the EUKOM work. As pointed out in earlier sections of this brochure the immediate plans include the formation of both the EUKOM association and the certification body. Part of the association's activities will include completion of the level 3 training course content along with the examination material. In parallel to this activity, work will continue on the refinement of existing material for levels 1 and 2.

Due to the harmonized training concept it can be assumed that the certificate issued after successful passing the final examination will be accepted European-wide. To support this purpose they will be overseen by a European body for personnel certification.

Finally, it can be stated that EUKOM is a European training concept that meets all requirements of world-wide use. Modular structure and multi-language versions of platform and materials allow learners all over the world to access training materials in their native language provided that they have access to the internet. CMTRAIN is open to every person, institution or company that wants to support the philosophy of EUKOM.

ACKNOWLEDGMENTS

The authors wish to acknowledge the European Community for their support. This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

REFERENCES

[1] Weckenmann, A.; Gawande, B.: Koordinatenmesstechnik – Flexible Messstrategien für Maß, Form und Lage. Hanser Verlag, München, 1999

[2] Beetz, S.; et al: Ausbildungskonzept Koordinatemesstechnik – AUKOM. In: FQS (ed.): Project reports. FQS-DGQ-Band 81-01 (2002)

[3] Rebaglia, B.I.; Balsamo, A: CMM training. In: European Quality Today. 04/05 1999. p. 34

[4] Großmann, J.; Beetz, S.: Methodology Design Report. Erlangen, 06/2004. www.eukom.com, 2005.

[5] Weckenmann, A. et al: Training Concept EUKOM. Erlangen, 06/2004. www.eukom.com, 2005.

[6] Weckenmann, A.; Beetz, S.: EUKOM – European Training for Coordinate Metrology. In: International IMS Forum 2004. (Cernobbio, Italy, May 17th - 19th, 2004). Proceedings, p. 1381-1389.

[7] Weckenmann, A.; Beetz, S.: EUKOM – European Training for Coordinate Metrology via the Internet. In: Joint International IMEKO TC1+TC7 Symposium (Ilmenau, Germany, September 21st – 24th, 2005).

[8] Weckenmann, A.; Durakbasa, M. N.; Osanna, P. H.: European-wide Unified International Education in the Area of Co-ordinate Metrology. In: Argentinean- Austrian Days for Metrology and Automation with European Participation, October 2004, Buenos Aires

[9] Weckenmann, A.; Blunt, L.; Beetz, S.: European Training in Coordinate Metrology. Components of a training concept: Situation - Curriculum - Methodology - Training system - Experiences. impuls Nr. 20, Ed.: National Agency Education for Europe, Erlangen. 2005.

[10] www.cm-train.org, 2005.