

## **TRAINING ON BASICS FOR INDUSTRIAL METROLOGY BY INTEGRATION OF WORK AND LEARNING IN THE PROJECT MESS-IN**

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**Abstract:** For the correct performing of measurement tasks, the operator needs a lot of knowledge in many fields. As so far there is no education for becoming a metrologist in Germany, in the project Mess-iN a comprehensive training for advanced vocational education in metrology was developed. The course consists of two phases: A learning phase focusing on the gathering of knowledge and a project phase focusing on the transfer of knowledge into daily practice. The course is accompanied by a tutor.

The imparting of knowledge in the first phase is designed as Blended Learning. Web based learning modules are combined with workshops to provide both a high degree of freedom in learning and the possibility for hands-on-training and direct communication. During the project phase the participants work on a real metrological problem. Thus lack of knowledge or understanding will show up early and can easily be resolved. Additionally, by working on the project the participant is encouraged to communicate his newly gained competencies to his colleagues. Therefore he acts as a disseminator of knowledge. By that integration of learning into working, the course Mess-iN offers an efficient education for metrology and enhances the long term success of the training.

**Keywords:** Blended Learning, workplace-integration, advanced training, cooperative learning, informal learning

### **1. INTRODUCTION**

In the manufacturing of modern products small tolerances and narrow margins of time lead to high demands on the accuracy as well as the efficiency of industrial measuring. To fulfil these requirements the operator needs on the one hand extensive skills in the handling of his measuring machines and devices, on the other hand profound metrological knowledge to choose an apt measuring device, to set up a proper measuring and evaluation strategy and generally to avoid mistakes and thereby reduce influences on the measurement.

This general knowledge is of especially high significance, since in modern machines mistakes in handling are checked and corrected or marked by the control software whereas mistakes in the developing of measuring strategy

and thus arising faulty measurement results are rarely noticed. Also general metrological knowledge is independent of special machines and therefore valid for a long time. In contrast skills in handling the machines or programming measuring routines are in most cases useful for only one type of machine, provided by a single manufacturer with a specified version of software.

As so far there is no vocational education for metrologists in Germany, the operators have to gather all needed information during advanced training. Yet the existing offers for further education in metrology are mainly provided by manufacturers of measuring machines. These therefore focus strongly on the handling of the specific machine and accordant software whereas basic principles are only rarely and very fragmentarily taught. Other courses are about very specific topics and not always adapted to the needs and preknowledge of the average operator. Therefore information often has to be gathered by self conducted inquiries in standards, books or internet. Of course this does not always lead to a satisfactory understanding of complicated subjects. So problems occurring in the gaining and interpretation of measuring results, whether between customer and supplier or between different sections of an organization, are often caused by misunderstanding or a sheer lack of knowledge.

Therefore the project 'Mess-iN – Messtechnik - Lernen im Netzwerk' (Metrology – Learning in a network) aims at the development of a comprehensive basic metrological training, focused on the needs of operators in industrial measuring. Thereby also the framework for the future development of a vocational training in manufacturing metrology can be laid.

### **2. CONCEPT OF THE COURSE MESS-IN**

Further vocational training has to fulfil two important requirements: On the one hand it has to impart the knowledge in such a way, that the participants are able to transfer it into their daily work and use it to solve their particular problems. On the other hand it has to regard economical aspects and should not cause high costs for the employer. This second requirement is of special importance regarding training for basics of a subject, because the benefits are gained only on long term, whereas benefits of machine spe-

cific training show up immediately. As the positive effects of a profound understanding are on short term less visible, basic training is often regarded as a pure factor of cost. However, to fulfill both requirements, an adequate form of training has to be chosen. There it has to be considered, which aims of learning are to be achieved and which methods and facilities are required for that.

### 2.1. Analysis of training methodologies

The participants of the training shall gather knowledge about metrological principles, methods and standards and also be able to use these skills competently in their daily work. Therefore the imparting of theoretical information has to be supported as well as using the lessons in practical problems. As the training is supposed to be a measure of advanced education, the concept has to provide a high degree of freedom for the participants, regarding adjustability to different preknowledge, experiences and interests as well as fitting with requirements of professional work and everyday life.

Conventional attendance-based education or training offer nearly unlimited possibilities to design learning contents via presentations, group work, exercises, hands-on-training on measuring devices and so on. Also they allow for exchange among the students and for direct communication and feedback between teacher and student, so difficulties in understanding become evident and can be cleared immediately. But the contents of a seminary have to be adjusted to the whole group of participants, only in a strictly limited margin it is possible to react to the needs of a single person. Also, conventional face-to-face seminars cause high costs for the organization - regarding traveling, accommodation and the need for a stand-in to fulfill the participants' daily duties.

An efficient way to avoid these difficulties of lacking flexibility and high costs of participation is to use eLearning offers. These allow for the use of a wide spectra of media to impart information and offer a high degree of freedom for the single learner, as the velocity of learning and the choice of content can be conducted by each participant individually. Using web based learning systems, various ways of communication can be established. The costs of participation are low, as the learning due to the high flexibility can be easily adapted to existing requirements in work and no need for traveling or accommodation occurs. But with eLearning offers it is not possible to provide possibilities for practical experiences. Yet especially in the field of metrology it is important to transfer the gathered information to the performing of measuring tasks.

Therefore both methodologies are not apt for an exclusive use in an advanced vocational training for metrology.

### 2.2. Blended Learning concept

To combine the specific advantages of both attendance based training and eLearning, the course Mess-iN is implementing a Blended Learning concept. The contents are imparted via a combination of web based learning modules and workshops, which take place in regular intervals. As a spe-

cial focus has to be set on the transferability of knowledge to daily work, the course consists of two phases: The self conducted gathering of knowledge, supported by a tutor (learning phase) and the transfer of gathered knowledge into the daily routine by working on a project, which requires the use of newly gathered skills to solve a metrological task (project phase). Finally in an examination the skills of the participants are tested. To receive the certificate it is necessary to be successful both in the examination of theoretical knowledge and in working on the project.

By a User Needs Analysis it was checked, whether there is interest for this kind of training concept among the intended target group of measuring operators and if the necessary conditions for a successful participation are given, because the use of a concept, which is not accepted by the participants or can not be used properly due to lacking infrastructure or circumstances, will not lead to any success in teaching. The analysis showed that the concept of Blended Learning was of great interest for the target group, whereas pure eLearning as well as pure seminars were not considered appropriate due to missing possibilities of practical experiences respectively to being absent from work and home. The necessary infrastructure for the use of web based contents – a computer connected to the internet – is available. Also the acceptance of a course with free timing and therefore a lot of own responsibility is high as well, as the readiness to learn in spare time and in addition to daily duties. [1]

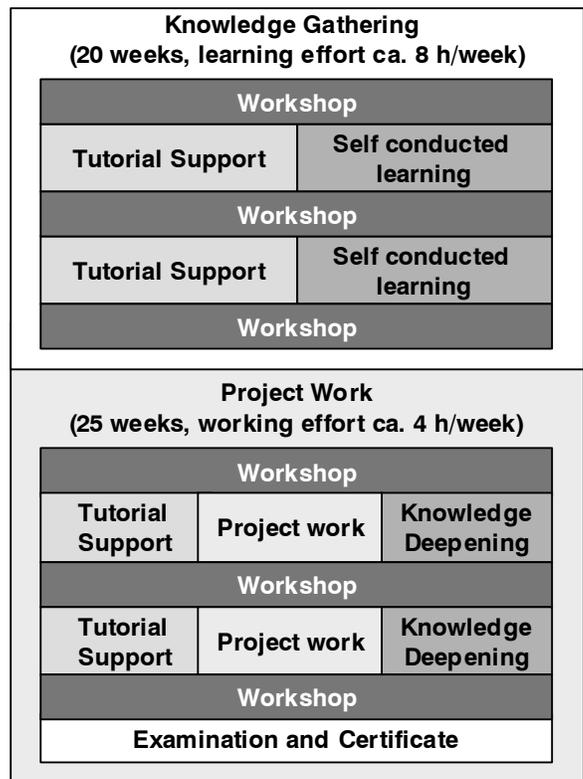


Fig. 1: Concept of the course Mess-iN

### **2.3. Learning modules for self conducted learning**

In the modules theoretical information is presented by explanatory texts enlivened with plenty of graphics and animations. New terms are defined in a glossary and the given explanation will be shown, if the term occurs in the written text. So misunderstanding due to missing knowledge of specific terms is avoided. For additional information and background knowledge, the modules include excurses and links to accordant pages in internet. The participants can choose the level of detail for a topic and get additional explanations if desired. So the contents can be easily adapted to the specific interests of the learner as well as to his already existing knowledge and skills.

To help the learner to judge, how much he knows about a topic, the learning aims and the contents of the module are specified in the beginning of each module. Further on, there are self-tests included, so the learner can easily evaluate his current state of knowledge and understanding by answering the questions and exercises. So deficits can be detected soon and be smoothed out immediately. For each module a working sheet is available for the participants containing mostly exercises which require the use of new information as well as its linking with other data and with existing knowledge. The working sheet is to be filled in and handed in for correction. The tutor will examine the paper and give a feedback according to the performance. So the learning progress of the participants is made visible and the tutor is able to give advice according to the current state of each learner.

During the self conducted work on the modules, a tutor is always available for support. The tutor needs experience and skills in measuring as well as pedagogical competencies, to support the learners adequately. If any questions occur during the work on the learning modules, the tutor can be contacted via phone, mail or by posting the problem in the discussion forum. Thereby misunderstanding can be recovered and difficult points can be explained. This does not only include questions on the contents but also technical problems, such as difficulties in handling the modules. Also the tutor can help the participant in finding additional information about topics of special interest by recommending appropriate sources.

### **2.4. Workshops**

In the workshops the theoretical contents of the learning modules are discussed and trained in practical exercises. For that, the measuring devices and machines of Chair QFM are used to perform typical tasks. This transfer of theory into practical work and the linking of theoretical information with own experiences is very important for the correct use of the gathered knowledge in the daily duties of the participants, as only the application of information is able to evidence, if it was really understood. Working on exercises in the workshops shows the state of knowledge of the participants. Difficulties, lacks and misunderstanding arising during the discussion can be cleared immediately either by the tutor or by the other participants.

The workshops additionally provide the possibility for a direct feedback between learners and tutor and for an ex-

change and social interaction among the participants. This supports the atmosphere of being in a course and reduces the problem of feeling left alone when working on difficult new contents. Also the exchange among the measuring operators can lead to a spreading of experiences and best practice examples and therefore has a direct impact on the quality of daily work as well as on the motivation to attend the course.

At the beginning of the course there is an additional start workshop where the participants meet each other and the tutor. Especially the acquaintance with the tutor lowers considerably the inhibition threshold to ask for support when necessary. In the start workshop also the individual background of the participants is asked and their aims and reasons for attending the course. This information is important for the constant improvement of the training in order to meet the needs of the participants. A main topic of the start workshop is also the introduction to the handling of the platform and the modules. Thus – combined with handing over a manual – difficulties in using the platform can be avoided.

### **2.5. Project phase**

For the phase of project work following the phase of knowledge gathering, a task is set for each participant. This task consists of a problem regarding measuring or the later use and processing of measuring results. Over all, the amount of work for the project task should be about 80 hours. The project is chosen in close cooperation with the organization of the participant in order to grant, that solving the task is useful for the organization. The project consists of a subject, which is abundant to the usual daily duties of the participant and requires using the newly gathered skills to solve the problem. Thereby the learning process is enhanced and the readiness to accept and transfer new information to improve the usual work is increased. [2]

During their work on the project, the participants always have the possibility to fall back on the tutors, if any questions occur. So the transfer of the provided knowledge can be eased. In the workshops during the project phase the learners first present their tasks, later they report on the chosen way of processing and currently occurring problems and finally present the results. So also soft skills are trained, such as presenting results of work and discussing possible ways of problem solution. This is new to most of the participants as cooperative working is not very common and not promoted in most German companies, especially on the level of blue collar workers. By the presentation and discussion of different tasks, the participants are encouraged to exchange experiences and provide a pool of ideas. So they also can take profit out of the others' tasks.

Working on the project basically supports the transfer of theoretically understood information into practical use. But it has impact, too, on the surrounding of the measuring operator. As metrology never is an isolated task but is closely connected to other areas in the organization, such as construction, manufacturing or quality assurance, colleagues and cooperating persons become aware of the work on the project, as it is out of routine. This promotes the exchange of

information and thereby also the spreading of knowledge. So the participants act as multipliers of knowledge in their organization and can actively help to improve the cooperation between the different sections to produce high quality products. So a transfer of knowledge is promoted, enhancing a sustainable effect of learning.

### 3. CONTENTS OF THE COURSE

The course Mess-iN consists of 12 modules covering fundamental principles of manufacturing metrology and corresponding German and international standards as well as properties and applications of various measuring technologies. Additionally methods and basic principles of quality management, in which the gathered measurement results are to be used, are imparted together with general requirements and activities for the achieving of precise, comparable measurement results.

The contents of the course are based on the results of the former European project METROeLEARN, a pure web based course targeted for the education of engineering students in manufacturing metrology. [3] The topics analyzed there to be necessary for a compulsory training in metrology were used as framework for the choosing of contents for the course Mess-iN, amended by a module containing basic knowledge of important terms, mathematics, physics and inscription of tolerances in technical drawings. This information is necessary for the understanding of more complex measuring and evaluation principles. Choosing contents that are not limited to the pure explanation of metrological principles but also include more general topics of quality management, shall rise the awareness of the measuring operators for their position in the value added chain and their responsibility for contributing to high quality results.

Dependent on the complexity of each topic, the modules require a different amount of work. To ease the scheduling of learning for the participants, in each module an overview of the presumably necessary time to work on a topic is given. Of course this is only an estimation, as the actually necessary time depends a lot on the personal abilities and properties of the learner and the preknowledge regarding the specific subject, but anyway is considered helpful by the participants as it gives an orientation.

The course content with the total workload of each module and the timetable is shown in the table below. The modules are separately made visible, following a certain timetable. Before the fixed date the participants are not able to access them. By this fixed scheduling and structure the learners are supported to work systematically and purposeful on the single modules. This is especially important as most people in the target group have no or only small experience in self controlled learning, as vocational education and training is mainly conducted in seminars. Nevertheless the scheduling is held rather loose to provide enough freedom to arrange learning according to other duties. Also, the contents are still visible after the end of the intended working time and thus can be repeated arbitrarily. All in all, the course is spread over a whole year.

Table 1: Contents of the course

	Content	Work-load	Schedule in weeks	
Learning phase	Start workshop learning phase Introduction to course structure and learning platform	8 h (1 d)		
	1 Basic knowledge	18 h	1 <sup>st</sup> – 3 <sup>rd</sup>	
	2 Traceability of measurement results	18 h	3 <sup>rd</sup> – 5 <sup>th</sup>	
	3 Coordinate metrology	22 h	5 <sup>th</sup> – 9 <sup>th</sup>	
	4 Form testing	14 h	9 <sup>th</sup> – 12 <sup>th</sup>	
	1 <sup>st</sup> Workshop Practical exercises for modules 1-4	16 h (2 d)		
	5 Surface testing	14 h	13 <sup>th</sup> – 15 <sup>th</sup>	
	6 Optical measurement technologies	14 h	15 <sup>th</sup> – 17 <sup>th</sup>	
	7 Metrology in quality management	6 h	17 <sup>th</sup> – 18 <sup>th</sup>	
	8 Inspection planning	10 h	18 <sup>th</sup> – 19 <sup>th</sup>	
	9 Quality assurance of measurement results	4 h	19 <sup>th</sup> – 20 <sup>th</sup>	
	2 <sup>nd</sup> Workshop Practical exercises for modules 5-9	16 h (2 d)		
Break (if desired)				
Project phase	Start workshop project phase Presentation of project tasks	8 h (1 d)		
	Project conduction (ca. 40 h)	10 Measurement rooms	5 h	21 <sup>st</sup> – 24 <sup>th</sup>
		11 Machine tool testing	10 h	24 <sup>th</sup> – 31 <sup>st</sup>
		12 Special applications	8 h	32 <sup>nd</sup> – 35 <sup>th</sup>
	3 <sup>rd</sup> Workshop Practical exercises for modules 10-12; Presentation of interim results and problems	16 h (2 d)		
	Project conduction	ca. 40 h	35 <sup>th</sup> – 45 <sup>th</sup>	
Final workshop Repetition of all modules; Presentation of project results	16 h (2 d)			
Examination for Certificate 'Certified Metrologist'				

### 4. TECHNICAL REALISATION

The training course Mess-iN is implemented as a web-based learning system on the platform ILIAS [4]. The platform features numerous functions, that enable a good communication among the participants and between participants and tutors. Nevertheless, the use of the platform is easy, even for persons not used to browsing in the internet. There are discussion forums, an integrated email system and a group system, that allows for cooperative working

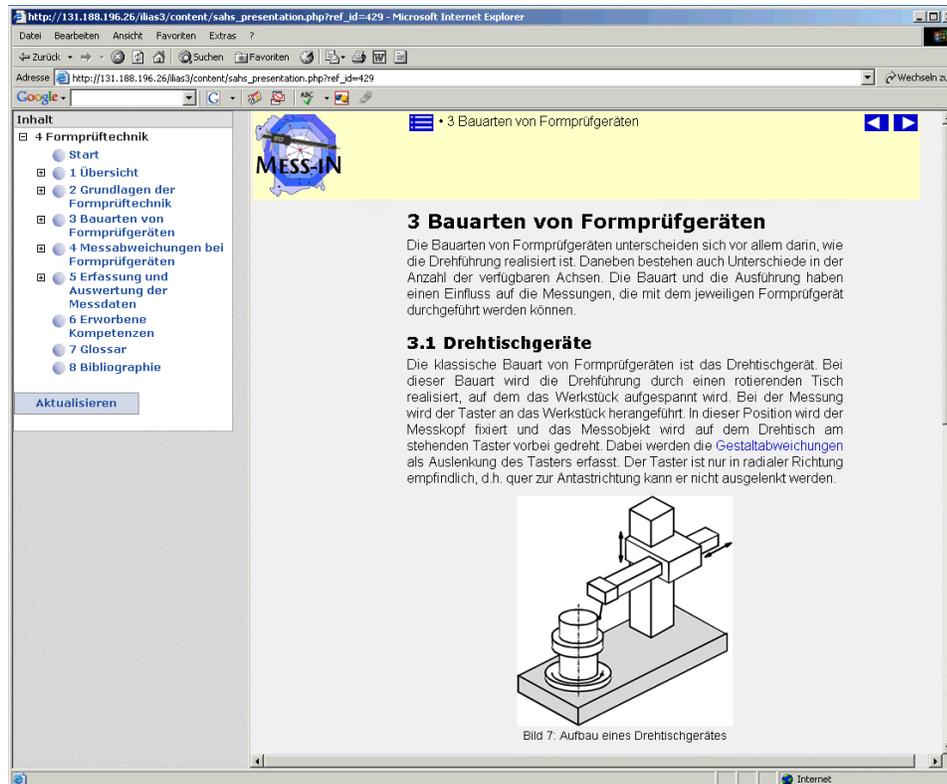


Fig. 2: Screenshot of learning module

The modules are fit in the platform using the widely accepted standard SCORM. That standard grants, that the modules can be exported and imported in other platforms as well. Thus there is no dependency of the chosen platform [5]. The modules are presented in the platform and can be used there. On these the learners can work online and parallel or later take contact with each other or with the tutor via the different communication facilities of the platform. Additionally the modules are made available in a version for offline learning. So the learner does not have to be connected to the internet all the time.

Also the exercise sheet are provided in the platform for download. Additional information and documents can also be put there for the participants. This includes for example documentation of exercises in the workshops. By the coherent presentation of learning modules, exercise sheets, tools for cooperative working and communication, the web based learning platform builds the centre of the course and is used as the main facility for exchange and learning.

## 5. MEASURES OF QUALITY MANAGEMENT AND EVALUATION

To establish a comprehensive quality management is very important especially for educational measures. Trainings that impart contents in an unsatisfying way, incorrect or incomplete, may cause a lot of problems on the long term – additionally to the financial loss of course charges – if the participants take wrong decisions or perform their tasks wrongly because of a lack of knowledge. Especially for

eLearning courses it is therefore necessary that all the learning materials provide easy comprehensibility and unambiguousness, because questions to the tutor or the discussion with other participants is always delayed and in spite of the various communication facilities connected with a previous effort. Therefore compared to seminars difficulties in understanding become evident later, so that unsatisfying or ambiguous explanations have a much stronger influence on the learners compared to conventional training offers. [6]

For the evaluation and continuing improvement of the learning material and the course concept in general, a feedback is asked of the participants. On the one hand this is done directly in the workshops, on the other hand the web based evaluation tool eValue is applied for a holistic summative as well as formative evaluation of both the results and the work in the project. The tool eValue is based on the model for evaluating business excellence by the European Foundation for Quality Management (EFQM) and was developed at Chair Quality Management and Manufacturing Metrology for the evaluation of eLearning projects conducted there [7], [8]. There not only the resulting materials are evaluated, but also the whole development of the course during the project. Weaknesses in the method can be made visible to be avoided in future projects. In this evaluation the participants as well as their advisors are involved, the workers on the project and the experts regarding didactics and content. As the tool has been used for the evaluation of other projects before, a comparison is easily possible and allows for an objective rating of the results.

By this double evaluation on long term and on short term, the quality of the training can be comprehensively judged. Weaknesses are smoothed out as soon as possible and thus lead to a continuing improvement of the learning system Mess-iN. Also potentials for improvement are considered in the development and performing of following courses.

## 6. DISCUSSION OF CURRENT RESULTS

A pilot course of Mess-iN has started in May 2005 with 13 participants of a large variety of companies, mainly SMEs, and has concluded in April 2006. A second course started in February 2006. The participation in these pilot courses is free of charge due to the support of European Social Fund (ESF).

The first experiences clearly show that there is a broad interest in a basic training for measuring operators, although there were some retentions regarding the self conducted learning in the web based platform. The average participant clearly is not used to advanced training in the scheme of life long learning and has little or no experience in the field of eLearning or internet use in general. Nevertheless, the participants adjusted well to the training concept and were able to handle the platform easily.

The participants stated, that the gathered knowledge was useful for their daily tasks and that a better understanding of basics had a strong effect on their decisions in daily routines. Especially impressive are the results gathered in the projects. According to the variety of companies the project tasks differed a lot. In organizations with more than one participant, the possibility to work in a team on a larger project was given and well accepted. The definition of appropriate tasks included a visit at the company and a discussion with the participant and the supervisor, where the idea of the project was explained and an appropriate task was set. The desired impact of the project work on the surrounding was strongly noticeable. Many participants gave account about discussions with colleagues following their activities in the project and of support by their supervisor. The feedback in the companies was noticed to be very positive and it was often stated by the participants, that substantial changes in methods of measuring and quality management as a whole arose out of the newly gathered knowledge, spreading also in other departments. Therefore most participants identified strongly with the success of their project and were willing to contribute even their spare time.

Generally, the feedback of the participants was positive. Yet according to the results gathered in the final evaluation, the structure and material of the course will be optimized to impart useful, transferable knowledge in an efficient and attractive way, adapted to the needs of the target group.

## 7. CONCLUSION AND OUTLOOK

By the development of the Blended Learning course Mess-iN a learning system was created, which allows measuring operators to gather knowledge necessary for the proper and efficient conduction of their tasks, in a way that integrates both learning and working. However, the success and

the acceptance of the training among employers and participants depends on the actuality and functionality of the platform and the proper performance of the workshops. So after the project conclusion a commercialisation will be necessary to provide the required funds to maintain and update the platform.

But in any case the developed course shows a possibility for the integration of learning into work and thereby contributes to the transforming of the former antagonism of working and learning into a mutual support. Thus the positive effects of profound understanding of basic principles can be used to enhance a continuous improvement of quality and reproducibility in the conduction of measuring tasks.

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