

Report on the Measurement Uncertainty Training Workshop

17 – 18 May 2022

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MATHMET



Preamble

- › MATHMET is a European Metrology Network (EMN) with the objective of creating a sustainable structure in Mathematics and Statistics for metrological applications.
- › The Activity MU Training is part of MATHMET's strategic agenda and work plan, which are both important elements in the establishment of the MATHMET EMN as a sustainable structure.
- › The Parties working together in the MATHMET Activity MU Training aim at improving the quality, efficiency and dissemination of measurement uncertainty training.
- › They contribute to 1) developing new material for measurement uncertainty training and 2) establishing an active community for those involved in measurement uncertainty training.



Document description

- › The document is the report of the (virtual) *Measurement Uncertainty Training Workshop* organized on 17-18 May 2022 as part of activity A2.2.2 of MU Training activity led by PTB.
- › The workshop gathered nearly 40 participants from 25 organisations to share good practice and experience in MU training, to learn from teaching experts, and to know how to target audiences at the end of the measurement chain.
- › The partners participating in the report were
 - MATHMET members: LNE, INRIM, IPQ, METAS, NPL, SMD
 - › Non-MATMET members: NSAI (National Standards Authority of Ireland), DAM (Deutsche Akademie für Metrologie), UKN (University of Konstanz)
 - Stakeholder participating in the report: Testo Industrial Services GmbH
- › This powerpoint file contains summary slides provided by the participants to capture and summarize the lessons learned from the workshop with main messages from the talks.
- › The programme and the presentations can be downloaded from the EURAMET website [EURAMET: For Teachers - Measurement Uncertainty Training](#)



AUTHORS

The contact persons who filled in the slides are intended as the authors of the present document. They are identifiable at the top section of each slide by their names and affiliation.

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DISCLAIMER

The information related to the Measurement Uncertainty Training Activity has been provided by the authors.

All information collected are reported to the best of the authors' knowledge and are believed to be complete and accurate at the date of this document version.

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Overview of courses and classroom examples on MU evaluation

Survey of training courses on MU evaluation (Francesca Pennechi, INRIM)

- Aim of the survey (A1.1.2): overview of existing courses on MU, as a base for a framework of mutual attendance of training courses and sharing of the material
- Info collected: 41 courses, from 14 Partners and 1 Stakeholder, > 880 hours of teaching activity
 - General information: 50 % courses integrated into a training framework, 44 % focused on a specific field of application, the majority recurring, very different lengths, covering 9 languages, mostly held in person or online and 8 e-learning, 50 % with a final examination, 50 % with an enrolling fee
 - Target audience: 15 % legal metrology, 37 % NMI, 46 % calibration and testing labs, 24 % Academia (overlapping categories); mean number of attendees is 25
 - Technical contents: overview of probability (85 %) and metrology (95 %) topics, input uncertainties and LPU-GUM (almost all), LPU-JCGM102 (20 %), MCM-JCGM101 (44 %), MCM-JCGM102 (15 %); use of SW (68 %); main references: JCGM Suite, Standards, Guides, ...

Main message

Take home message

- MCM taught in almost no legal course, in a third of the calibration and testing labs, half of the NMI and most of the Academia courses
- 80 % courses do not treat multivariate models --> Gap?
- Those treating multivariate models, however, generally do it by both LPU and MCM



Overview of courses and classroom examples on MU evaluation

Survey of classroom examples on MU evaluation (Peter Harris, NPL)

- Two sources of examples
 - Survey of existing courses (as part of A1.1.2): 67 examples spread over 40 training courses
 - Compendium of examples from EMPIR project EMUE: 41 examples over 6 broad application areas
- Features of the examples are summarised using the categories
 - Application area; Metrology area; Approach (to uncertainty evaluation); Level (of difficulty)
 - Difficult to compare the two sources of examples in terms of application area
 - Examples taken from the two sources are complementary in terms of
 - Metrology area: Existing courses focus on examples related to dimensional and temperature measurement
 - Level: Existing courses focus on examples that are simple to medium in difficulty
 - Examples from EMUE offer a wider range of approaches: Bayesian, regression, “top-down” (ISO 21748), etc.

Main message

Take home message



Sharing best practices in MU training, Marc-Olivier André, METAS

Based on contributions from CEM-DAM-GUM-INRIM-IPQ-LNE-METAS-NPL-NSAI-PTB-SMD

- The MU training offering presented during the workshop is very diverse in terms of: target public, scope, mathematical level, business model.
- The Italian calibration and testing labs were informed by Accredia about the EMUE compendium. Many agree that launching a survey to collect feedback would be a useful action, among the Italian labs and beyond. The examples will be part of the future document JCGM 110.
- The importance was stressed to create a close connection between teachers and audience: follow a red wire throughout the curriculum, break the rhythm by bringing a variety of examples, make out of the course an experience, show empathy.
- Big difference between online course and e-learning: online is mostly quite passive and with minimal interactions, e-learning can be rich and lively, but provided it has been specifically designed having this in mind.
- A participant expressed interest for a curriculum or framework. There is a metrology curriculum resulting from a collaboration between an NMI and an academic institution in some countries (FR, PT, UK, IT). There is however no agreed curriculum on the European level to date.

Main message

Take home message

- Highly diverse MU training offering across Europe.
- Delivering an in-person course online is quite difficult and frustrating from the teacher's standpoint. E-learning offers quite interesting avenues for interaction.
- Make the course an experience for the participants!



Learning from teaching experts

NPL's training development process (Michael Lingard, NPL)

- The more effort you put into evaluating your audience, the better your training will meet their needs
- Considering training through the lens of receiving information, rather than giving it, might help you avoid cognitive overload and 'conceptual cliffs'

Main message

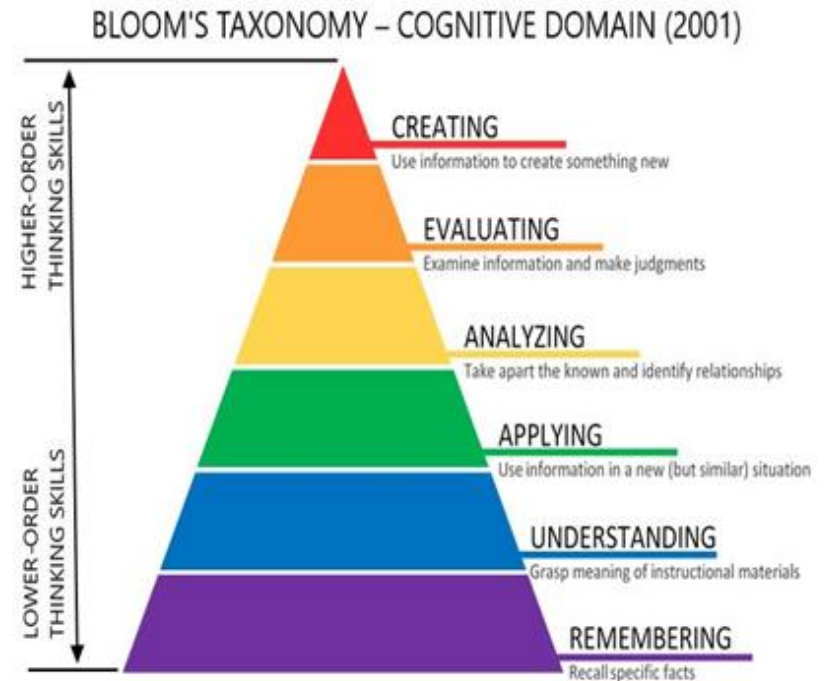
Take home message

- If you want to do serious online training, rather than just posting video recordings of webinars, there are lots of things to think about (such as accessibility) that take a lot of time and effort to implement well

Pedagogical choices for skills acquisition (Michèle Desenfant, LNE)

Main message

- **Understand** the formula of LPU → slides with hypothesis and demonstration of the formula
- **Understand** the usefulness of the sensitivity coefficients → slides with graphs
- **Apply** the LPU → basic exercise
- **Discover** the relative LPU --> guided exercise
- **Analyse** the LPU → practical work on the process of measurement of « g »





Learning from teaching experts

Overview of Research on Teaching Measurement Uncertainty (Philipp Möhrke, UKN)

Main message

- Research mainly on children in secondary education
- Understanding the concept of a **set** of measurements and the spread of its results as the key information for uncertainty takes time
- There are models on what to teach for a basis
- There are validated tests to evaluate the success of instruction
- Knowing the theory and applying it on examples does ensures that people apply their knowledge in the lab on real situations
- Flipped Classroom helps you with having more time for discussion, getting to know more about the problems of learners and the application of concepts in class

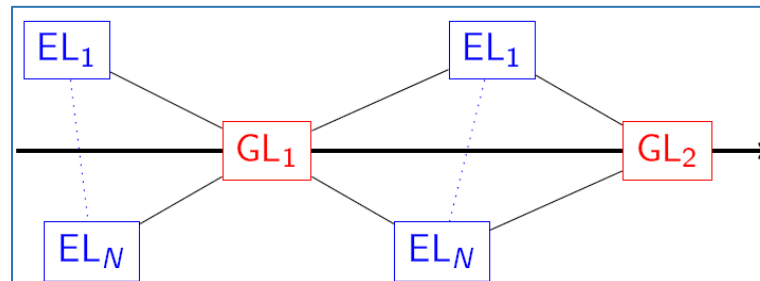
Take home message

- Try flipped classroom
- Build as many bridges between theory and application as possible

Project: implementation of flipped classroom at DAM (Cord Mueller, DAM)

Main message

- After "traditional" MU teaching (trainer-oriented presentations followed by exercises for the trainees), final oral exams reveal that our graduates do not acquire the desired fundamental understanding of even most basic concepts.
- DAM adopts a blended-learning scenario, where individual e-learning phases at home (EL_j) alternate with analogue group learning phases (GL_j) on site:



- "Flipped classroom" method promises to avoid cognitive overload and to smoothen conceptual cliffs, especially for trainees who are less mathematically literate.

Take home message

- DAM to implement flipped-classroom MU teaching in a blended-learning scenario



Targeting audiences at the end of the measurement chain

On the practical experiences of MU-trainings for laboratory and industry partners (Stefan Jurgeit, Christian Sander, Matthias Ohlrogge, Testo Industrial Services GmbH)

- ▶ Measurement uncertainty seminars need to be tailored according to target groups and focus areas:
- ▶ Basic uncertainty seminars
 - End-user community is not very interested in the underlying mathematical methods of statistics
 - Practice-oriented evaluation and reasonable estimates are required
 - Awareness of a balanced effort and benefit of the uncertainty evaluation
 - for “beginners” who want to create budgets according to the standard method; illustrated with several calculation examples.
- ▶ Industrial companies increasingly ask for consulting
 - Main focus is not to evaluate the uncertainty of a measurement result, but to **estimate precision of processes and evaluate specifications**
- ▶ Advanced uncertainty seminars
 - Optimize customer budgets and apply alternative methods
 - Correlated influencing variables (covariance)
 - When do I use which alternative to the GUM standard method?

We need to keep the GUM simple and practical



Targeting audiences at the end of the measurement chain

Teaching MU with a minimum of mathematical content (Oliver Power, NSAI)

Main message

- Many attendees at NSAI's MU Training Course are unlikely to perform uncertainty evaluations regularly and some not at all
- It is very important to firmly establish the basic framework for the evaluation method before dealing with the mathematical/statistical concepts and tools (this basic level of understanding is sufficient for many attendees)
- Practical and interactive exercises are very useful, especially when they are relevant to the audience
- Animations displaying the evolution of frequency distributions can be used to illustrate statistical concepts
- An annotated template of a simple uncertainty budget provides attendees with a convenient reference point

Take home message

- Tailor the course to meet the needs and background of the audience
- The formulation stage of the MU evaluation process is the most important
- Use illustrations and animations to demystify the maths/stats operations
- In the near future the data processing will be easily handled by user friendly applications
- Follow-up contact should be encouraged



Targeting audiences at the end of the measurement chain

MU course for the community of legal bodies (João Alves e Sousa, IPQ)

Main message

- Convey basic concepts of metrology (measurement, error and uncertainty)
- Interpretation of a calibration certificate
- Distinction between calibration and metrological verification
- A key aspect includes the relation between MPEV/MPES and measurement results (with expanded uncertainty)

Take home message

- Importance of measurement uncertainty
- The concept of conformity assessment is key in legal metrology
- Is it possible to provide simpler documents without loss of rigour?

Feedback from MU trainees in Belgium - an informal interview approach (Thierry Caebergs, Anne-Sophie Piette, SMD)

Main message

- Interviews of different actors (trainee/trainer/assessor) from Belgium : legal metrology, accredited lab, accredited body, tech. assessor, NMI staff ...
- Many people need MU, not necessarily for computation
- Ex. of teaching involving MU : « how to read a certificate »
- refresh courses : every 2-3 years ; ISO/IEC 17025 induces some periodicity
- Model-based approach of GUM not applicable* for analytical measurements (testing labs, majority of accreditation scopes) ; instead, top-down approach is well (ex.: Eurachem guide), sampling and control chart are of interest
- Balance cost/benefit for following a training (SMEs)
- MU is a factual argument for instrument decision (spec., new, choice ...) and decision of conformity : it helps in explaining

Take home message

- Real examples, not simplified with real pictures, real data, real Excel spreadsheet
- Address the needs of the trainees : goals, and thus know who they address (« indirect trainee/customers ») = end-of-chain needs
- Concept of uncertainty more than its computation
- Basic training (very basic math level) then topical (with more advanced MU computation)

* result of the interviews, not an absolute truth