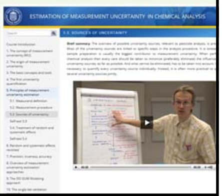
Using MOOCs for teaching analytical chemistry: experience at University of Tartu

Ivo Leito

ivo.leito@ut.ee

sisu.ut.ee/measurement



I. Leito, I. Helm, L. Jalukse. *Anal Bioanal Chem* (2015) 407:1277–1281

Massive Open Online Courses

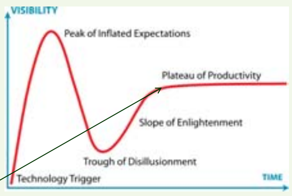
- Term coined in 2008
  - by D. Cormier and G. Siemens
- MOOCs were hailed as the **future of higher education**
  - 2012: „Year of the MOOC“ by NYT
- Since then, a lot of criticism
  - insufficient interaction between teachers and students, low course completion rates, etc
  - It is acknowlegded that MOOCs **were orginally overhyped**

Cormier D (2008) *The CCK08 MOOC – connectivism course, 1/4 way*. Available from Dave Cormier's blog. http://davecormier.com/edblog/2008/10/02/the-cck08-mooc-connectivism-course-14-way/

Pappano L (2012) The year of the MOOC. *The New York Times*, Nov 2, 2012

I. Leito, I. Helm, L. Jalukse. *Anal Bioanal Chem* (2015) 407:1277–1281

MOOCs: still very promising

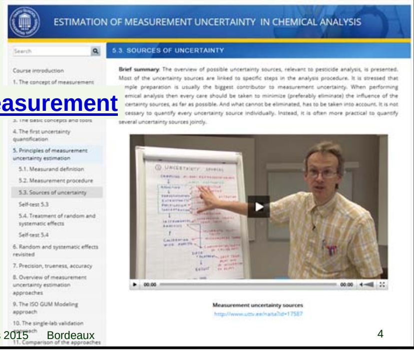


"Gartner Hype Cycle" by Jeremy Kemp at Wikipedia. Licensed under CC BY-SA 3.0 via Wikimedia Commons

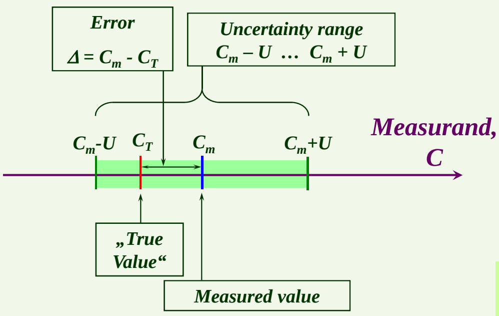
- MOOCs have **undoubted advantages**
- Offered by may leading universities
- Offered by many online providers
  - Coursera, edX, Udacity, …

On-line course: Estimation of measurement uncertainty in chemical analysis

sisu.ut.ee/measurement



Value, error and uncertainty



Measurement result

- This way of writing:

  The benzene content of a fuel is
  $C_{benzene}$ = (32 ± 6) mg/kg, *k* = 2, norm.

  Estimate of measurement uncertainty

- Is a **measurement result** and means the following:
  The true content of benzene in the fuel is in the range of 26 … 38 mg/kg with the approximate probability 95%
- The "± 6 mg/kg" is the **measurement uncertainty**
  - It is the expanded uncertainty

Why do we need measurement uncertainty estimates?

Measurement uncertainty

- Comparison with permissible limits
  Necessary for enforcing legislation
- Comparing two results
- Required by ISO 17025
- Optimizing measurement procedures
- Quality assurance of decisions
  Required in legislation
- Following trends in industry and labs

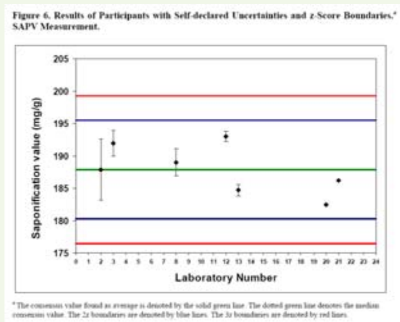
Measurement uncertainty in Chemistry

- **„Notoriously difficult“** ← **In practice: often underestimated uncertainties**
- Needs:
  - In-depth understanding of the particular chemical analysis procedure: physical-chemical principles, influencing factors
  - Knowledge and skills in mathematics (random quantities, distribution functions, …)
- Chemical analysis usually cannot be modeled well

Teaching measurement uncertainty

- **Very difficult** ← **It is usually taught at the level of basics but difficulties emerge first of all with practical applications**
- Usually taught in connection with analytical chemistry
- Many guideline materials and courses
- **Most of them stop exactly at the moment when it starts getting interesting and useful**

Consequences?



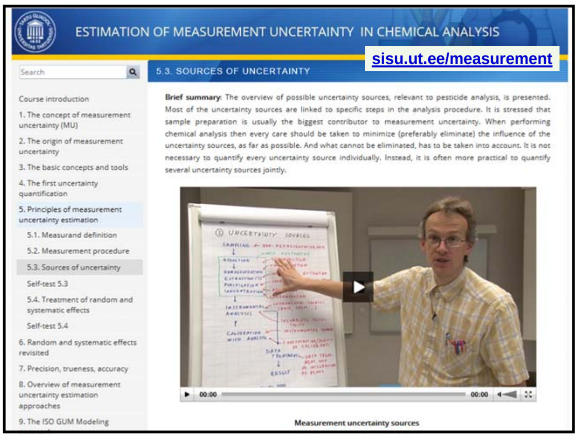
***EstOil-5 Final report*, 2009**
http://www.ut.ee/katsekoda/ILC/

Our goal

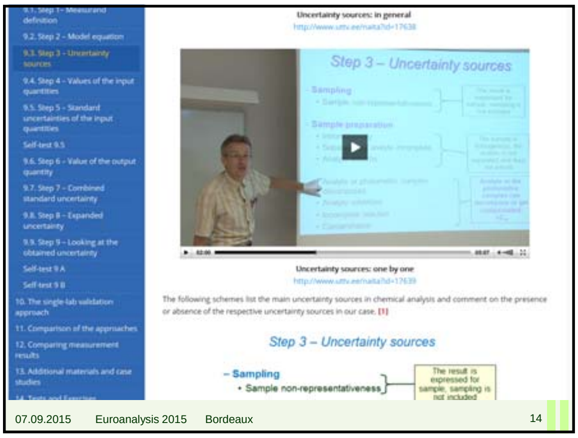
- Web-based teaching material for
  - **Independent** learning to estimate measurement uncertainty **in real-life situations**
  - On-line **reference point** of explanations of concepts and approaches
  - **Support for auditorial teaching** of metrology in chemistry at UT
  - Offering as **MOOCs**
- Required previous knowledge
  - General analytical chemistry knowledge

Course contents

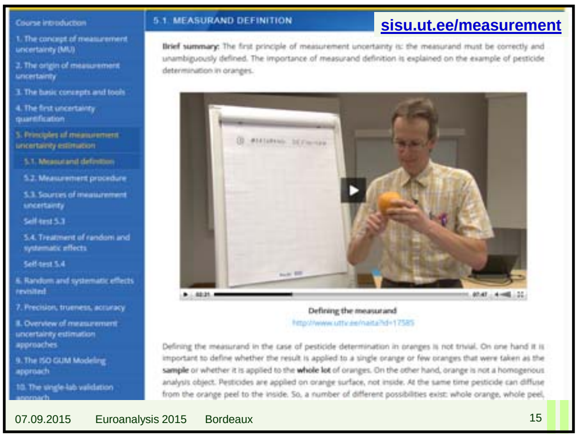
- **Theoretical** basis as well as **practical** skills
- **Detailed** and **example**-based treatment
  - Modeling (ISO GUM)
  - Within-lab validation (Nordtest)
- Close to **50** short **video lectures**
  - Supplemented by textual explanations and downloadable slides and calculation files
- Numerous **tests** and **calculation exercises**
  - Understanding of main concepts
  - Calculation exercises from **real life** situations
  - **Feedback** is given



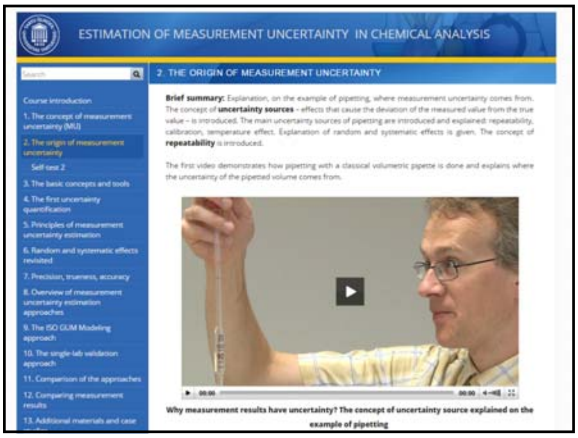
ESTIMATION OF MEASUREMENT UNCERTAINTY IN CHEMICAL ANALYSIS
sisu.ut.ee/measurement
5.3. SOURCES OF UNCERTAINTY
Brief summary: The overview of possible uncertainty sources, relevant to pesticide analysis, is presented. Most of the uncertainty sources are linked to specific steps in the analysis procedure. It is stressed that sample preparation is usually the biggest contributor to measurement uncertainty. When performing chemical analysis then every care should be taken to minimize (preferably eliminate) the influence of the uncertainty sources, as far as possible. And what cannot be eliminated, has to be taken into account. It is not necessary to quantify every uncertainty source individually. Instead, it is often more practical to quantify several uncertainty sources jointly.
Measurement uncertainty sources



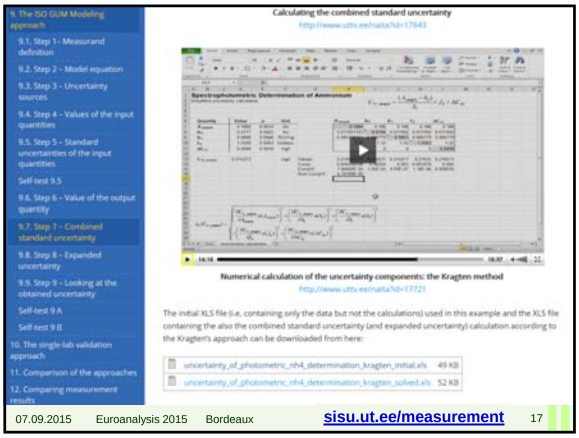
Uncertainty sources: in general
Step 3 – Uncertainty sources
Uncertainty sources: one by one
The following schemes list the main uncertainty sources in chemical analysis and comment on the presence or absence of the respective uncertainty sources in our case. [1]
Step 3 – Uncertainty sources
– Sampling
• Sample non-representativeness
07.09.2015 Euroanalysis 2015 Bordeaux 14



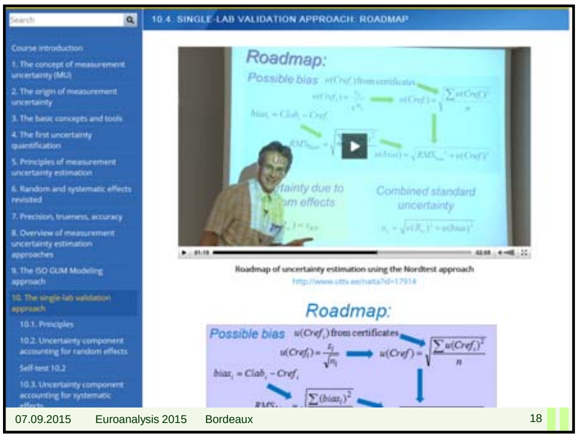
5.1. MEASURAND DEFINITION
sisu.ut.ee/measurement
Brief summary: The first principle of measurement uncertainty is: the measurand must be correctly and unambiguously defined. The importance of measurand definition is explained on the example of pesticide determination in oranges.
Defining the measurand
07.09.2015 Euroanalysis 2015 Bordeaux 15



ESTIMATION OF MEASUREMENT UNCERTAINTY IN CHEMICAL ANALYSIS
2. THE ORIGIN OF MEASUREMENT UNCERTAINTY
Brief summary: Explanation, on the example of pipetting, where measurement uncertainty comes from. The concept of uncertainty sources - effects that cause the deviation of the measured value from the true value – is introduced. The main uncertainty sources of pipetting are introduced and explained: repeatability, calibration, temperature effect. Explanation of random and systematic effects is given. The concept of repeatability is introduced.
The first video demonstrates how pipetting with a classical volumetric pipette is done and explains where the uncertainty of the pipetted volume comes from.
Why measurement results have uncertainty? The concept of uncertainty source explained on the example of pipetting



Calculating the combined standard uncertainty
Numerical calculation of the uncertainty components: the Kragten method
07.09.2015 Euroanalysis 2015 Bordeaux sisu.ut.ee/measurement 17



10.4. SINGLE-LAB VALIDATION APPROACH: ROADMAP
Roadmap:
Roadmap of uncertainty estimation using the Nordtest approach
Roadmap:
Possible bias
07.09.2015 Euroanalysis 2015 Bordeaux 18

sisu.ut.ee/measurement

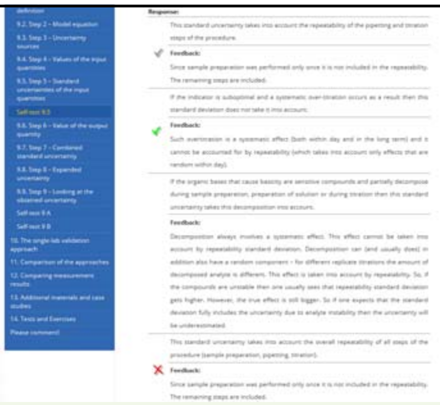
A laboratory wants to estimate the measurement uncertainty of protein content determination in different foods. For this protein content in a control sample of smoked sausage was determined repeatedly during a time period of almost one year. Every day when this smoked sausage was analysed only one parallel measurement was made. The following results were obtained:

Week	Result
	g/100g
3	18.1
5	20.5
11	18.3
14	19.1
15	19.3
27	20.2
34	19.7
41	19.5
42	18.6
48	20.1

In addition the laboratory analysed two certified reference materials: Ham with protein content (19.6 ± 0.6) g/100g (k=2, norm) and cheese with protein content (26.3 ± 0.7) g/100g (k=2, norm). The laboratory has carried out four bias determinations with the following results (each found value is found as a mean from a number of parallel measurements):

Reference value (g/100g)	Found value (g/100g)
26.3	26.9
26.3	27.2
19.6	20.1
19.6	20.4

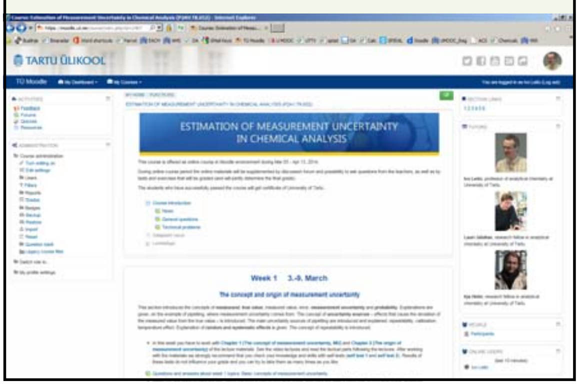
Please calculate the combined standard uncertainty of the protein determination procedure (please give 1 or 2 decimals). Absolute uncertainties can be used in this case.



Platforms

- Course contents: sisu.ut.ee
- Admin, forums, knowledge evaluation: moodle.ut.ee

MOOC: UT Moodle Environment

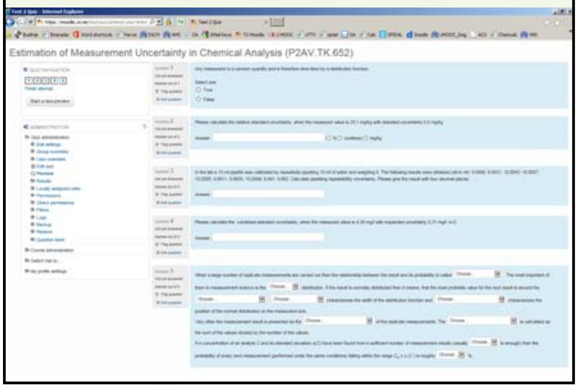


Divided into 6 weeks

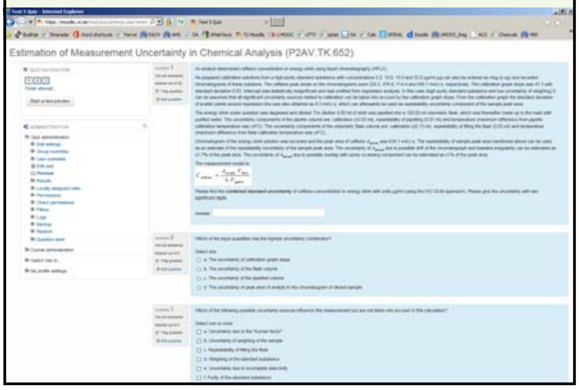
1. The **concept** and **origin** of measurement uncertainty
2. The basic **concepts** and **tools**
3. The **first uncertainty quantification**
   – On the example of pipetting
4. The **principles** of measurement uncertainty estimation (random and systematic effects and definitions for precision, trueness, accuracy)
5. Overview of the measurement uncertainty estimation **approaches**. The ISO GUM **modeling approach**
   – On the example of photometric determination of NH_4^+
6. The single lab **validation approach**. Comparison of different approaches. Comparing measurement results.
   – On the example of LC-MS determination of acrylamide

Weeks in Moodle

„Easy“ Test



„Difficult“ Test

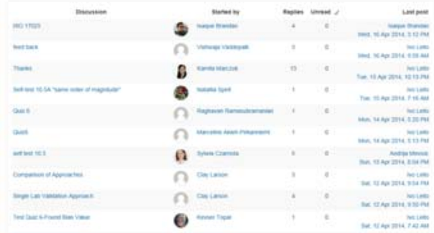


MOOC: Spring 2014 edition

270 participants from 40 countries!

High participation activity

- More than 300 posts to the forums
- Constant counseling by our team



Overall completion rate: 52%

Completion rate of those who started: 67%

MOOC: Spring 2015 edition

489 participants from 70 countries
(Forum activity still going on)

Overall completion rate: 34%

Completion rate of those who started: 60%

MOOCs vs „traditional“ teaching

I. Leito, I. Helm, L. Jalukse *Anal Bioanal Chem* (2015) 407:1277–1281

Aspect	Conventional university course	Practitioner training (short) course	MOOC
Interaction between students and teachers	Direct	Direct	Remote
Possibility to deliver the course simultaneously to many participants	Low	Low	High
Level of self-discipline needed from participants	Average	Average	High
Time constraints, time to "digest" the knowledge	Not a problem	Serious time constraints	Not a problem
Possibility of independent homework	Possible	Usually impossible	Possible
Possibility of hands-on problem-solving	Possible	Possible (within the time constraints)	Possible
Possibility of teamwork	Possible	Possible (within the time constraints)	Not easy
Possibility of experimental work	Easy	Possible, but not easy	Not possible
Possibility of working with participants of uneven level or preparation	Difficult but doable	Difficult	Possible
Possibilities of meaningful assessment of obtained knowledge	Wide possibilities	Difficult	Possible
Danger of cheating during knowledge assessment	Can be made low	Can be made low	Can be high
Costs of setting up the course[a]	Medium	Medium	Medium
Costs of running the course[a]	High	High	Low
Travel and accommodation costs	Can be high	Can be high	None

„Usage modes“

Estimation of Measurement Uncertainty in Chemical analysis
sisu.ut.ee/measurement

On-line course for independent learning
available any time anywhere

Course material
for running training courses e.g. by labs

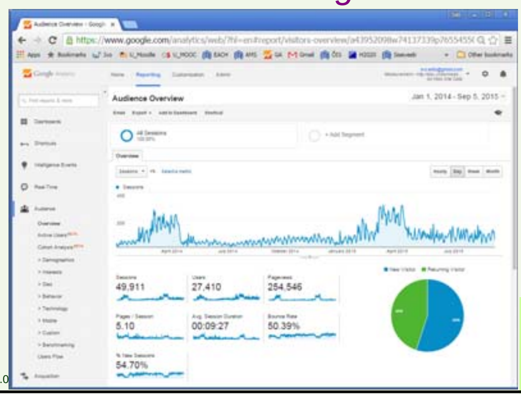
On-line reference point
of terminology, explanations and self-testing possibilities

Support to university teaching
Students can be directed here e.g. for self-testing

Running as MOOC
with registered participation, on-line counseling, graded tests and certificate

I. Leito, I. Helm, L. Jalukse. *Anal Bioanal Chem* (2015) 407:1277–1281

Visiting statistics



Many thanks to the team!

Materials development

Lauri Jalukse
Irja Helm


Video

Enno Kaasik

Web design, study administration

Triin Marandi
Lehti Pilt
Esta Pilt



Thank you for your attention!

MOOC – Third edition: Spring 2016
Registration will open in the beginning of 2016

sisu.ut.ee/measurement

I. Leito, I. Helm, L. Jalukse. *Anal Bioanal Chem* (2015) 407:1277–1281