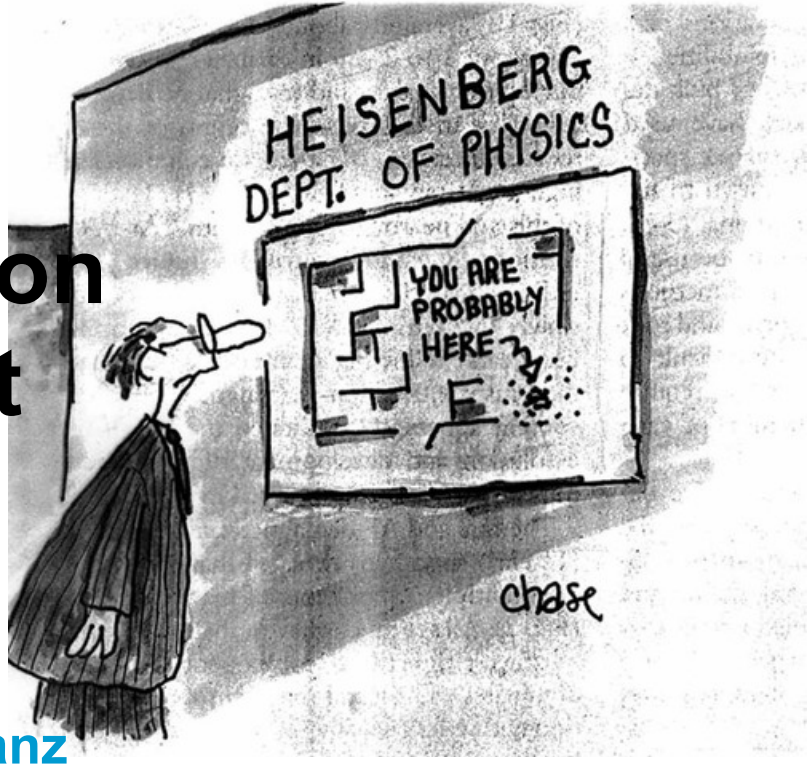
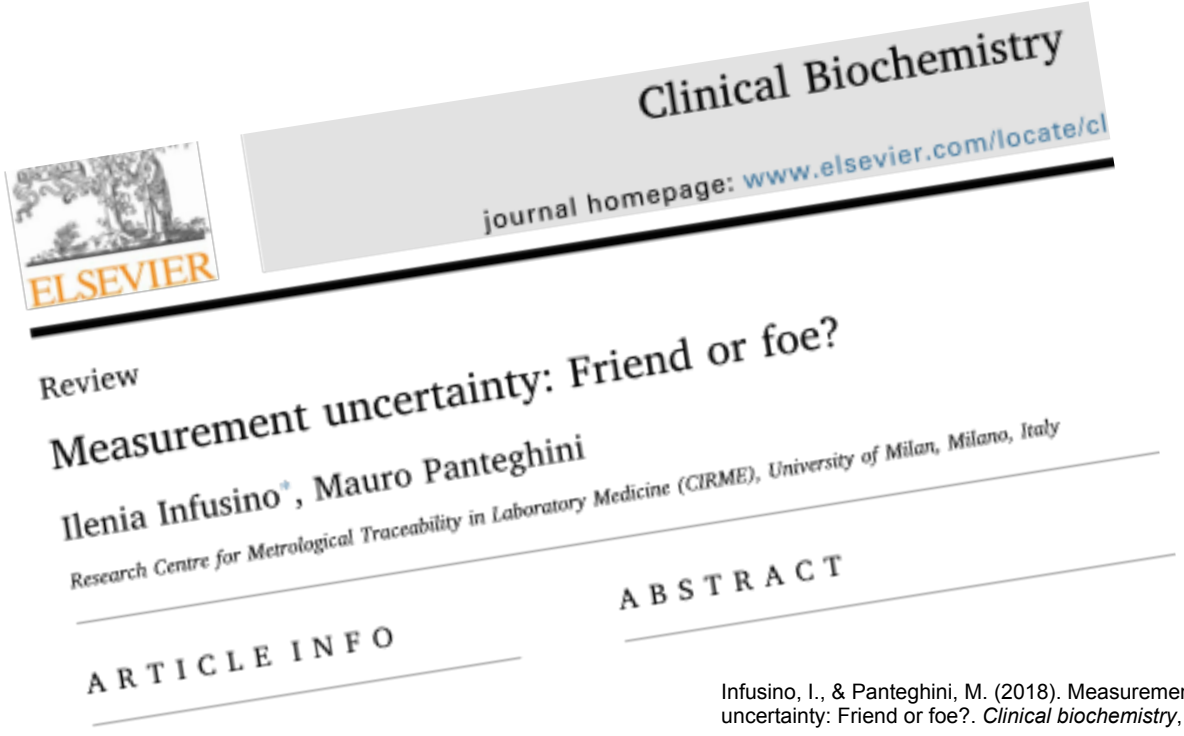
Universität Konstanz

Overview of Research on Teaching Measurement Uncertainty



Dr. Philipp Möhrke, University of Konstanz

Motivation



Clinical Biochemistry

journal homepage: www.elsevier.com/locate/cl

Review

Measurement uncertainty: Friend or foe?

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Research Centre for Metrological Traceability in Laboratory Medicine (CIRME), University of Milan, Milano, Italy

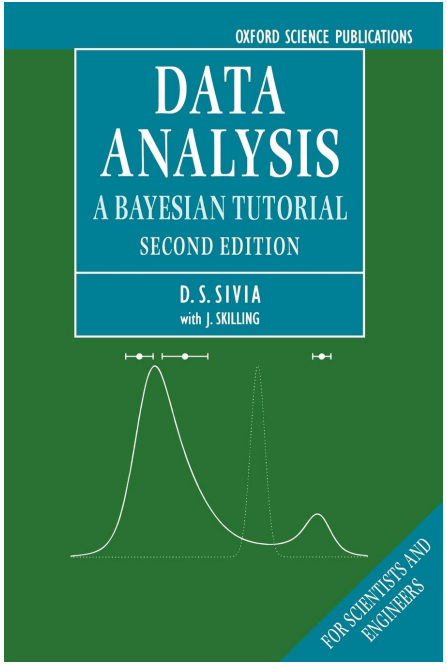
ARTICLE INFO

ABSTRACT

Infusino, I., & Panteghini, M. (2018). Measurement uncertainty: Friend or foe?. *Clinical biochemistry*, *57*, 3–6.

Problems

„The sense of unease which many of us have towards the subject of statistics is largely a reflection of the inadequacies of the ‘cook-book’ approach to data analysis that we are taught as undergraduates. Rather than being offered a few clear principles, we are usually presented with a maze of tests and procedures; [...]“



Known Problems

Sere *et al.* (1993)

- Reports from a course for first-year students at a French university
  - Theoretical input about statistics and measure uncertainty
  - Lab course focused on optics
  - Final test
- Results
  - About 50% fail in the final test
  - „Most of them had a poor understanding of the procedures and the advantage of statistics.“
  - No clear distinction between precision and accuracy.

M.-G. Séré, R. Journeaux & C. Larcher (1993) Learning the statistical analysis of measurement errors, International Journal of Science Education, 15:4, 427-438

Known Problems

Lubben and Millar (1996)

Following a paper and pencil test on experimental data suggested the progression model:

A	Measure once and this is the right value
B	Unless you get a value different from what you expect, a measurement is correct
C	Make a few trial measurements for practice, then take the measurement you want
D	Repeat measurements till you get a recurring value. This is the correct measurement
E	You need to take a mean of different measurements. Slightly vary the conditions to avoid getting the same results
F	Take a mean of several measurements to take care of variation due to imprecise measuring. Quality of the result can be judged only by authority source
G	Take a mean of several measurements. The spread of all the measurements indicates the quality of the result
H	The consistency of the set of measurements can be judged and anomalous measurements need to be rejected before taking a mean

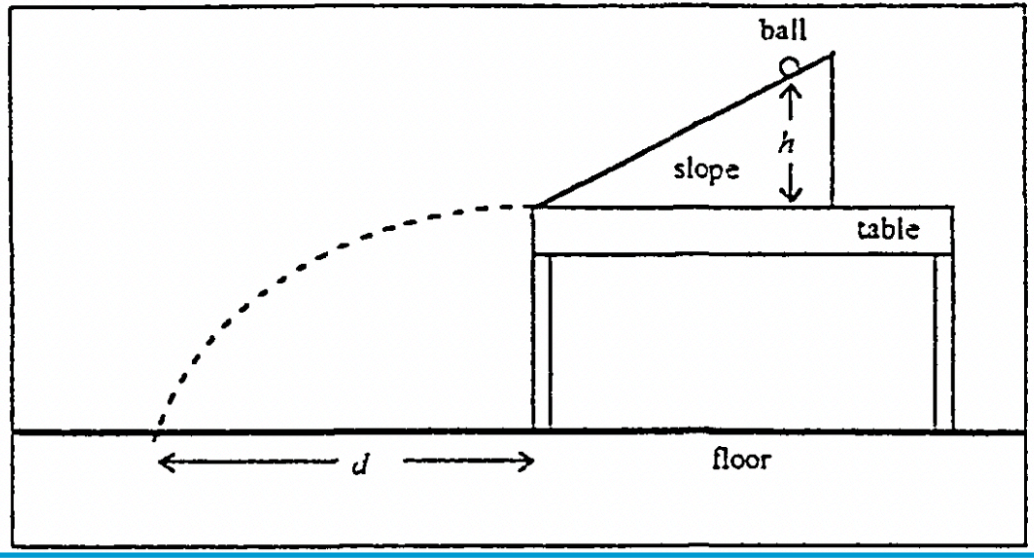
F. Lubben and R. Millar (1996) Children's ideas about the reliability of experimental data. International Journal of Science Education, 18 (8), 955-968.

Known Problems

Allie et al. (1998)

- first-year university s
  the University of Cap
- Pen and paper test b
  situations

An experiment is being performed by students in the Physics Laboratory. A wooden slope is clamped near the edge of a table. A ball is released from a height h above the table as shown in the diagram. The ball leaves the slope and lands on the floor a distance d from the edge of the table. Special paper is placed on the floor on which the ball makes a small mark when it lands. The students have been asked to investigate how the distance d on the floor changes when the height h is varied. A metre stick is used to measure d and h.

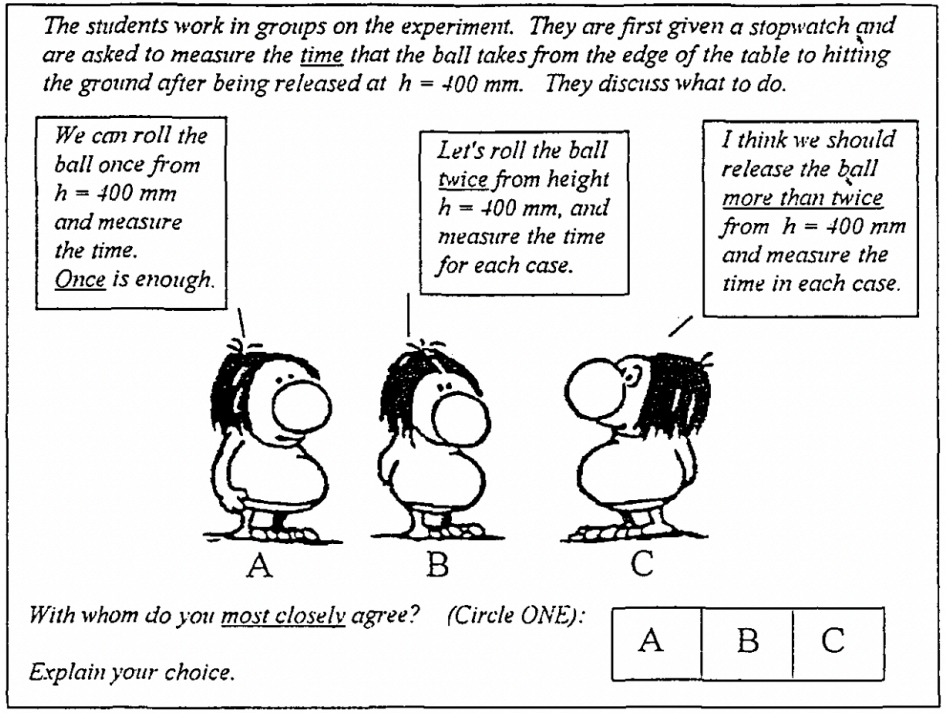


S. Allie, A. Buffler, B. Campbell & F. Lubben (1998) First-year physics students' perceptions of the quality of experimental measurements, International Journal of Science Education, 20:4, 447-459

Known Problems

Allie et al. (1998)

- first-year university science students at the University of Cape Town
- Pen and paper test based on lab situations
- Students can be categorized in two groups.



S. Allie, A. Buffler, B. Campbell & F. Lubben (1998) First-year physics students' perceptions of the quality of experimental measurements, International Journal of Science Education, 20:4, 447-459

Known Problems

Allie et al. (1998)

Point Paradigm

Each measured value is a indipendend candidate for being the true value.

- You repeat a measurement only to double check.
- When a value if found twice or more times it‘s the right one.

Set Paradigm

Each measured value only is a aproximation and carries only part of the information.

- You have to repeat a measure-ment to gain all information.
- The set of measurements is the result.

Recent research

Heinicke (2012)

- action guiding cognition

Hellwig and Priemer (2016)

- model of the subject

Existence of uncertainties
- Sources of uncertainty
- Distinguishing uncertainty from error

Handling of uncertainties
- Measuring objective
- Result of a measurement

Assessment of uncertainties
- Direct measurement: assessing a single uncertainty component
- Indirect measurement: propagation of uncertainty
- Expanded Uncertainty

Conclusiveness of uncertainties
- Reliability of a measurement and the result
- Comparison of a result with other values
- Fitting data to an expected curve

Priemer, B. & Hellwig, J. (2018). Learning About Measurement Uncertainties in Secondary Education: A Model of the Subject Matter. *International Journal of Science and Mathematics Education*, *16*(1), 45–68. https://doi.org/10.1007/s10763-016-9768-0

Recent research

Heinicke (2012)

- action guiding cognition

Hellwig and Priemer (2018)

- Model of the subject

Schulz (2022)

- Model of the subject

Example Item:

Laura wants to measure the mass of a crown cap. Unfortunately her scale shows a value of 0g.

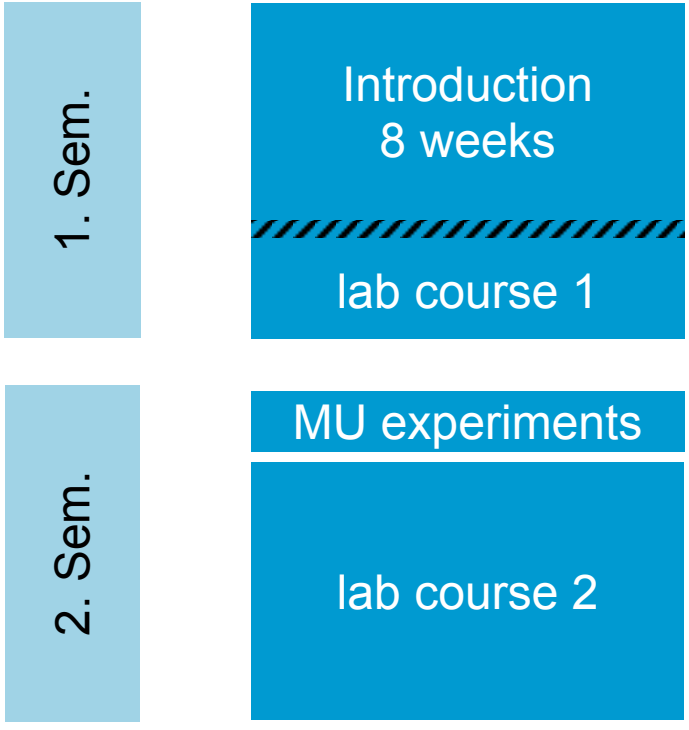
How can Laura adjust her measurement?

(More than one answer might be correct)

- Laura can use a more sensitive scale to measure the weigh of one crown cap.
- She can repeat her measurement (one cap on the scale) until the scale shows a value.
- Laura can wait until the scale shows a value that is different from zero.
- She can measure the mass of ten caps and divide this mass by ten.

Schulz, J. (2022). Entwicklung eines Testinstrumentes zur Erfassung von Kompetenzen im Umgang mit Messunsicherheiten.

Measurement Uncertainty @ UKN



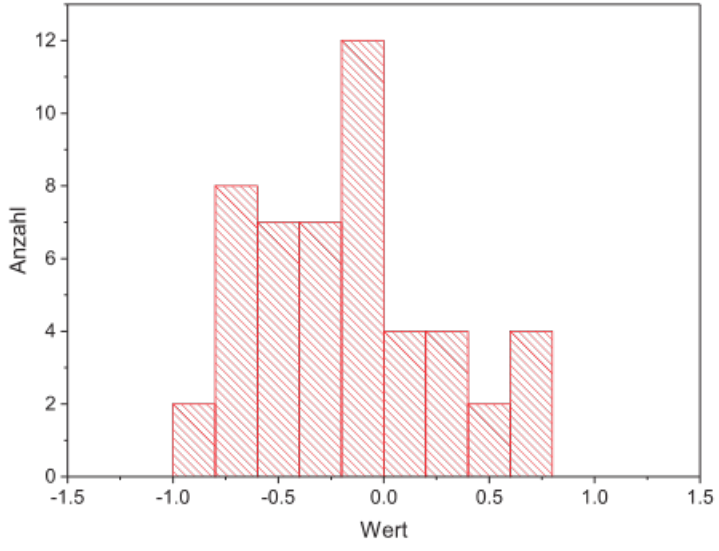
- repeated measurements
- distribution as result
- combining distributions
- single Measurements (estimate the distribution)
- notation of results
- modells
- lin. aproximantion für comb. uncertainties
- linear regression
- Comparing results (overlap of intervals)

The distribution is the basis

The result of every measurement is a distribution!

as data points

as intervall



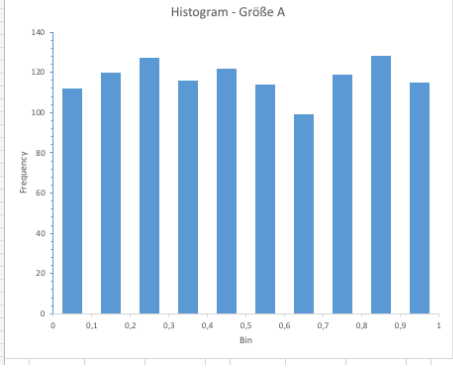
as histogram

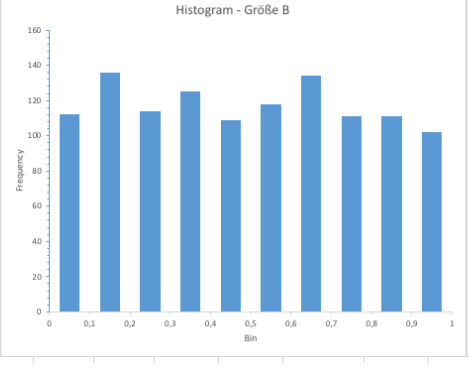
Example – Poor man's Monte Carlo simulation

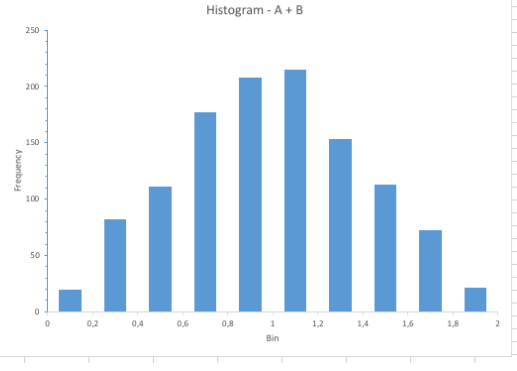
	Größe A				Größe B				A + B			
Bin	Frequency	Frequency last measurement	Frequency without last measurement	Bin	Frequency	Frequency last measurement	Frequency without last measurement	Bin	Frequency	Frequency last measurement	Frequency without last measurement
0				0				0			
	112	0	112		112	0	112		20	0	20
0,1				0,1				0,2			
	120	0	120		136	0	136		82	0	82
0,2				0,2				0,4			
	127	0	127		114	0	114		111	0	111
0,3				0,3				0,6			
	116	0	116		125	0	125		177	0	177
0,4				0,4				0,8			
	122	0	122		109	0	109		208	0	208
0,5				0,5				1			
	114	0	114		118	0	118		215	0	215
0,6				0,6				1,2			
	99	0	99		134	0	134		153	0	153
0,7				0,7				1,4			
	119	0	119		111	0	111		113	0	113
0,8				0,8				1,6			
	128	0	128		111	0	111		72	0	72
0,9				0,9				1,8			
	115	0	115		102	0	102		21	0	21
1				1				2			
		0,00	+			0,00	=			0,00	

Number of measurements 10000

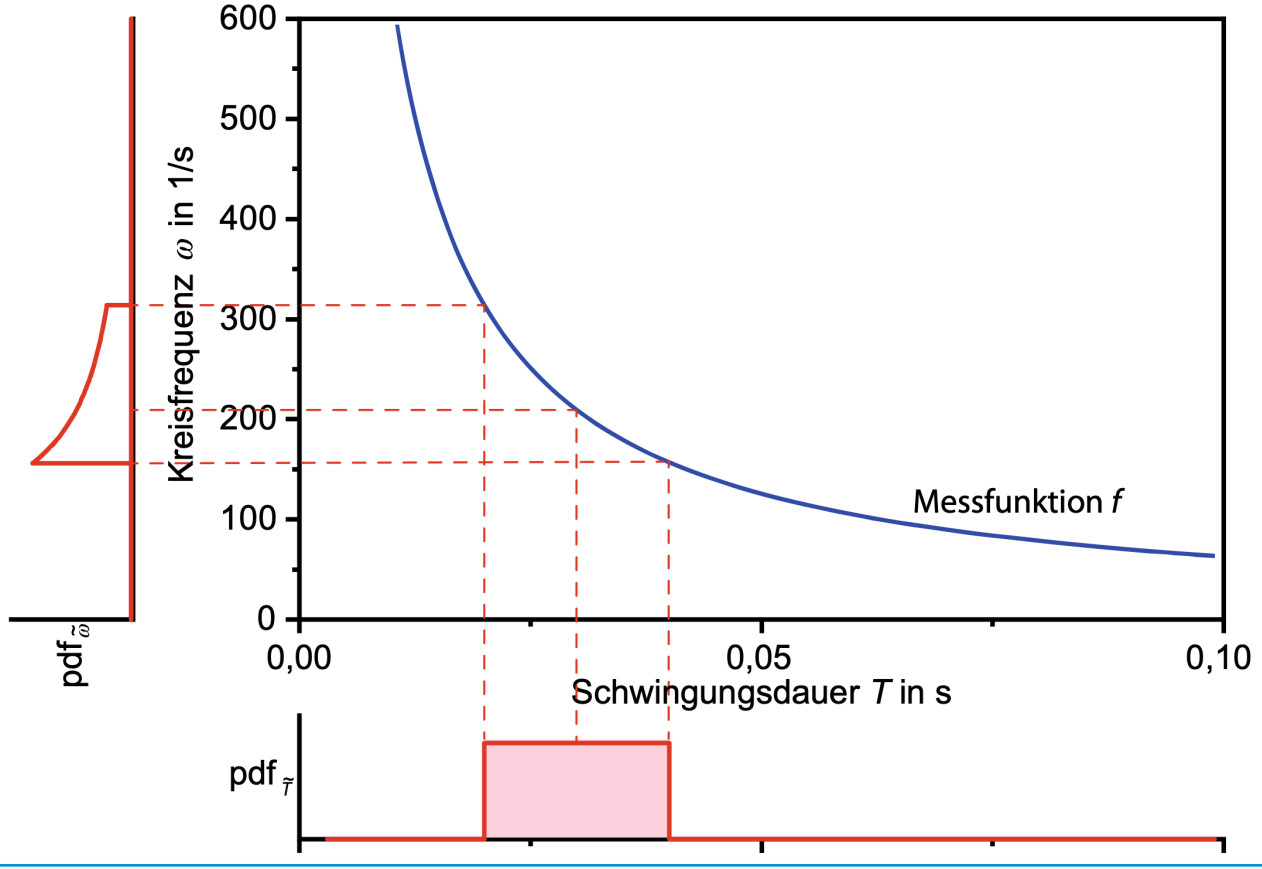
last measurement



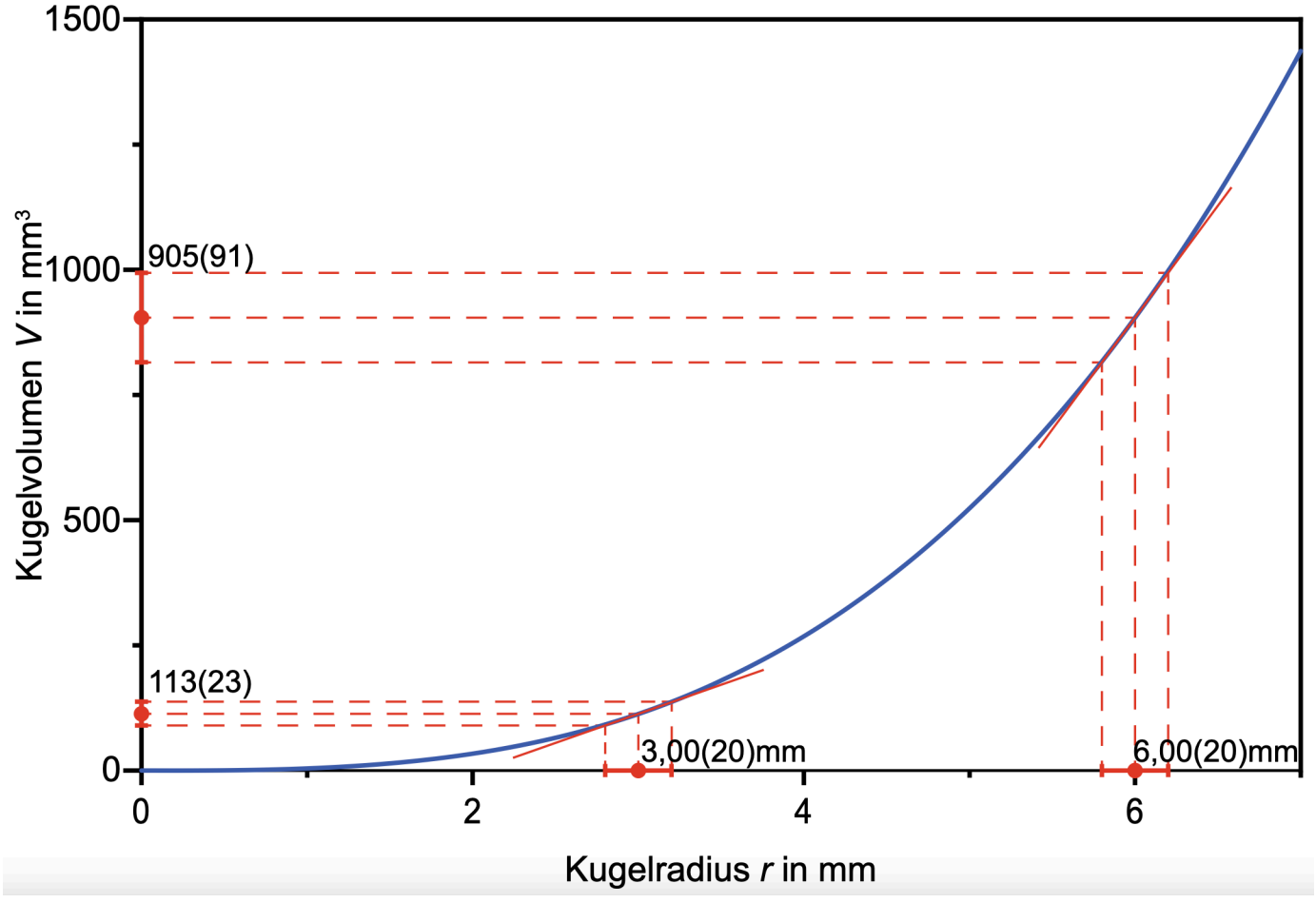




The effect of functions

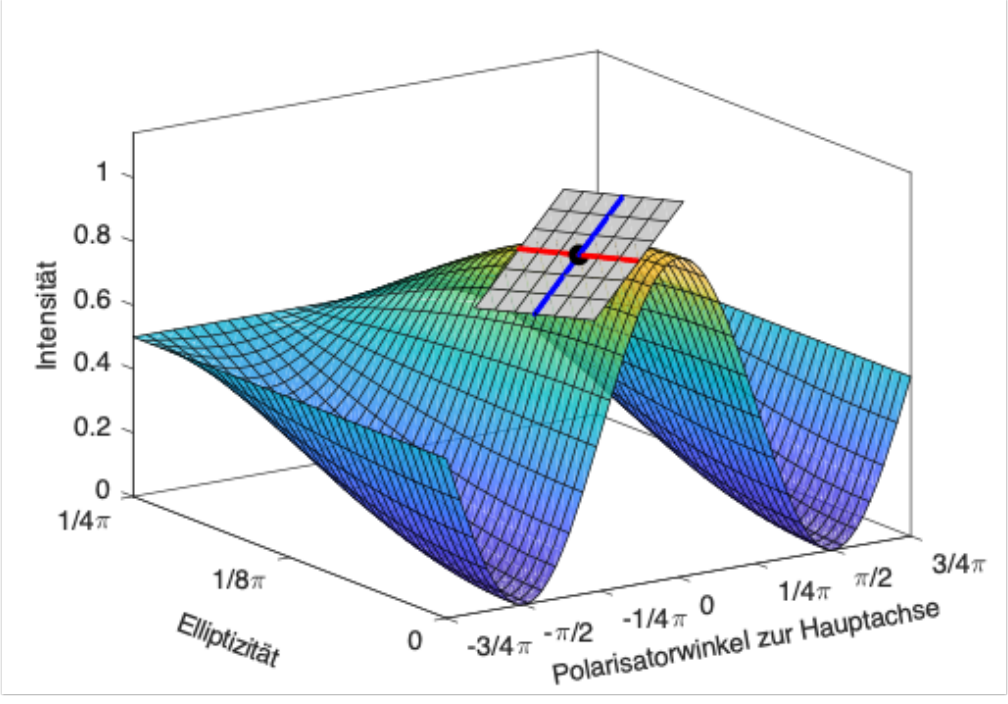


sensitivity coefficients



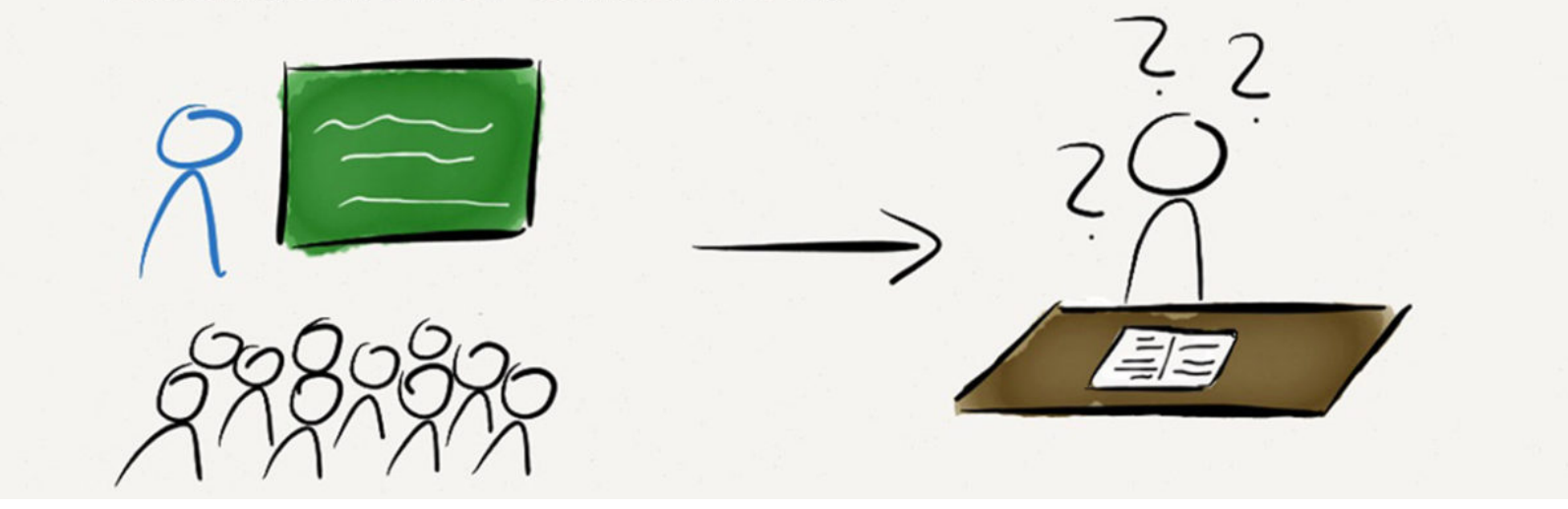
Combined uncertainty

$$u(z) = \sqrt{\left(\frac{\partial z}{\partial x} \bullet u(x)\right)^2 + \left(\frac{\partial z}{\partial y} \bullet u(y)\right)^2 + \ldots}$$



Flipped Classroom

Traditional Teaching



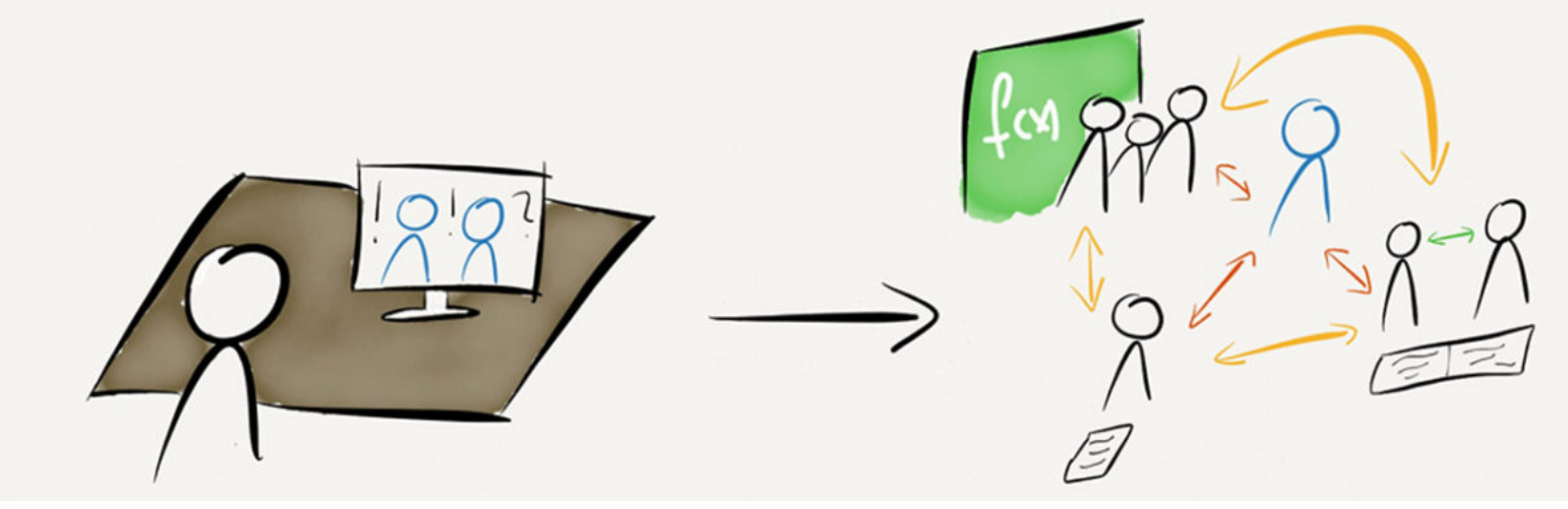
Input in class

Exercises/problems at home

http://www.fliptheclassroom.de

Flipped Classroom

Flip the Classroom

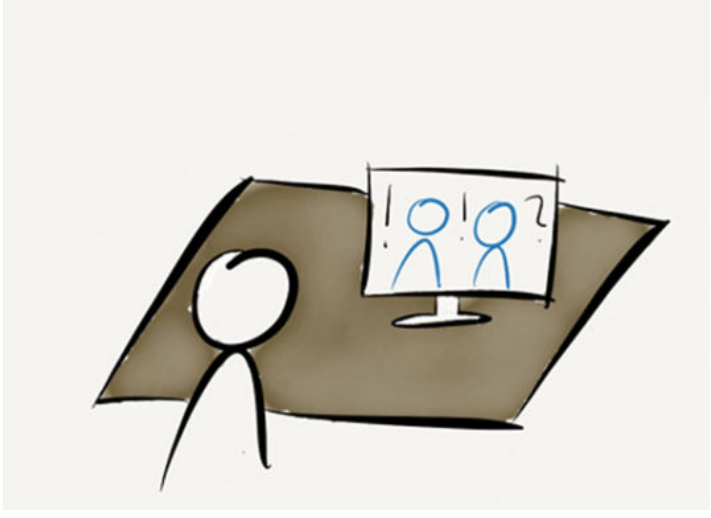


Input at home

Exercises and discussion in class

http://www.fliptheclassroom.de

Flipped Classroom



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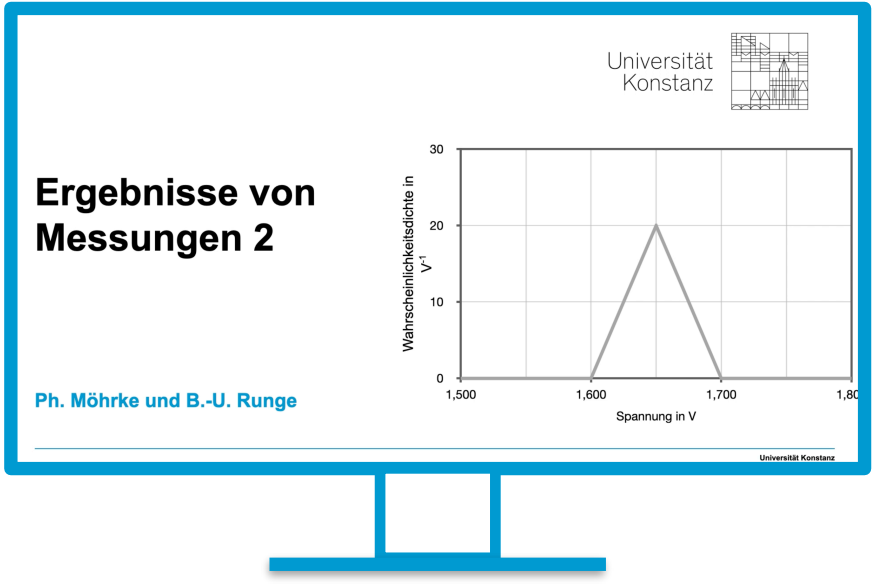
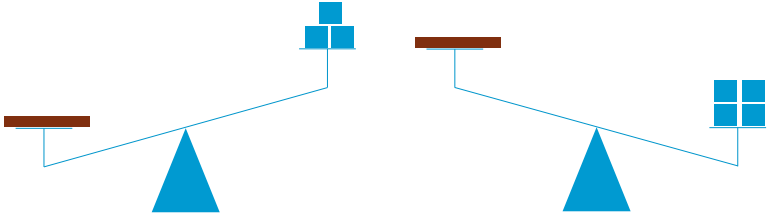


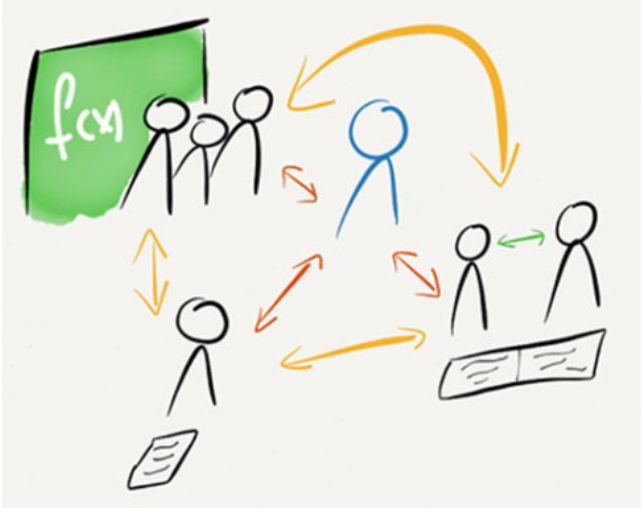
http://www.fliptheclassroom.de

Flipped Classroom

If you want to determine the weight of a bar of chocolate with a scale with the experiment shown, what would you note a the result?

Think yourself and discuss with others afterwards.





Exercises and discussion in class

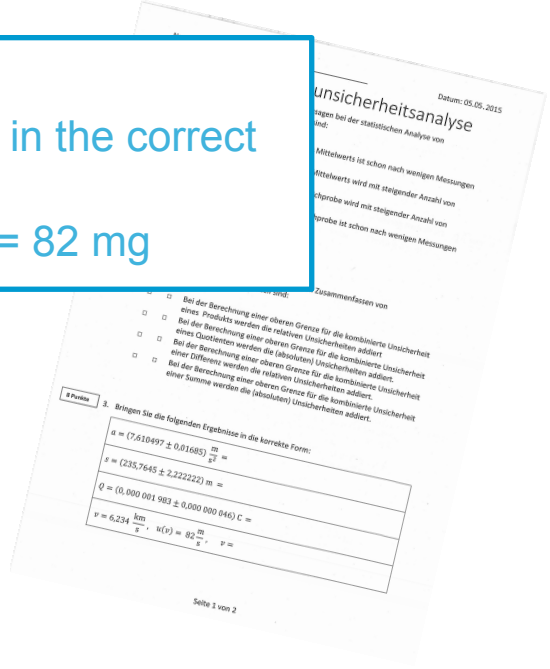
http://www.fliptheclassroom.de

Final test

- declarative knowledge

Rating of statements
„The standard deviation of a sample becomes smaller and smaller as the number of measurements increases.“

Write results
Write down the result in the correct form:
m = 6,234 g u(m) = 82 mg



- procedural knowledge

When measuring the density of a sample, you obtained the following values. What would you state as the result.

ρ in kg/m³	1,28	1,30	1,27	1,29	1,28

Final test

- declarative knowledge

Rating of statements	Write results
75 % reach full score (n = 62)	Mean result 0.75(2) (Mittelwert: 0.75, sd: 0.2, n = 62)

- procedural knowledge

Mean as result	95 % of students
Correct uncertainty	30 % of the students

Total:

0.75 of the points
(sd = 0.17)

Experiment test

Determination of the sinking velocity of a ball in a liquid

a) experimentally

by measuring the falling time with the aid of a stopwatch

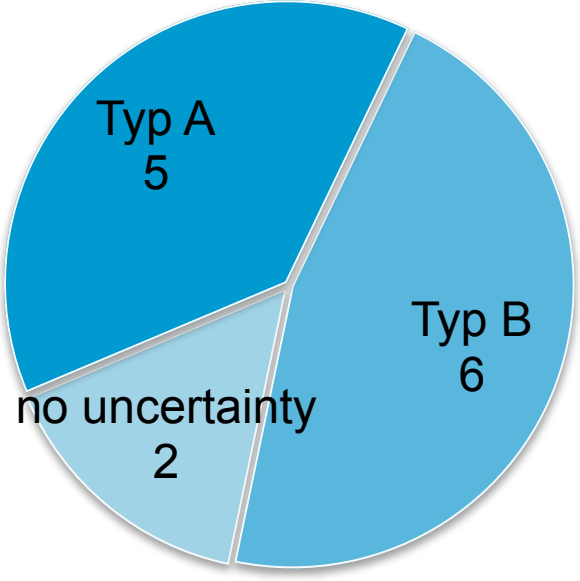
b) mathematically

by measuring the diameter of the ball and using a model

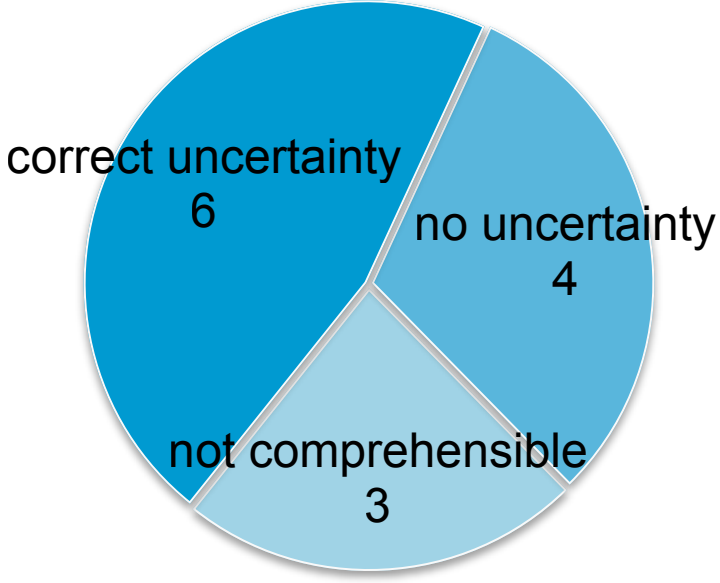
c) comparison of the results

Experiment test

Result of the experimental determination of the **sinking time**



Result of the experimental determination of the sinking velocity



Universität Konstanz

Thank you for listening!

Dr. Philipp Möhrke and Bernd-Uwe Runge
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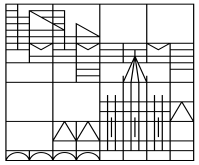
Universität Konstanz



Herzlichen Dank!

Dr. Philipp Möhrke und Dr. Bernd-Uwe Runge
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