Universiteit Utrecht

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Using class exercises to actively engage students in Structural Geology and Tectonics courses

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3rd year Earth Sciences Bachelor's degree course GEO3-1307

Structural Geology and Tectonics

Course Aims

By the end of the course, the student has acquired:

- a basic understanding of the processes involved in the development of crustal deformation structures, at the macro-, meso- and microscales;
- quantitative insight into the determination of deformation and strain, deformation history and paleostress state from the study of deformed rocks;
- the ability to recognise "structural styles" (associations of structures characteristic of specific tectonic settings) and an understanding of their development;
- insight into the features and processes that are important to consider in analyzing deformed terrains and in constructing tectonic models.

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Programme and examination – total study load 200 hrs.

- 4 lecture hours per week: 2x2 hrs
- 4 practical ("lab") hours per week = one afternoon mini-project team-of-two
- Weekly home assignments
- Total of 8 weeks: face2face and self study

- One intermediate exam (week 4), one final exam (week 9)
- Assessment and grading of the practical reports

Utrecht system of "Continuous Assessment"

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Structural Geology and Tectonics

Topics

- Tools for quantification:

  Strain measurement techniques, tensors and Mohr circles, strain in folds and shear zones

- Structures in the upper crust: fault patterns, structural styles
- Deformation behaviour of rocks:

  Brittle field

  Ductile field

- The anatomy of orogenic belts: from upper to lower crust, role of ductile deformation

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Structural Geology and Tectonics

The issue:

Constraints on classroom availability and (financial) limitations on the number of hours a lecturer is allowed to spend on a course (teacher load) make that we still schedule classical lectures.

Not the most effective way of making students learn.

The way out:

Interactive lecturing

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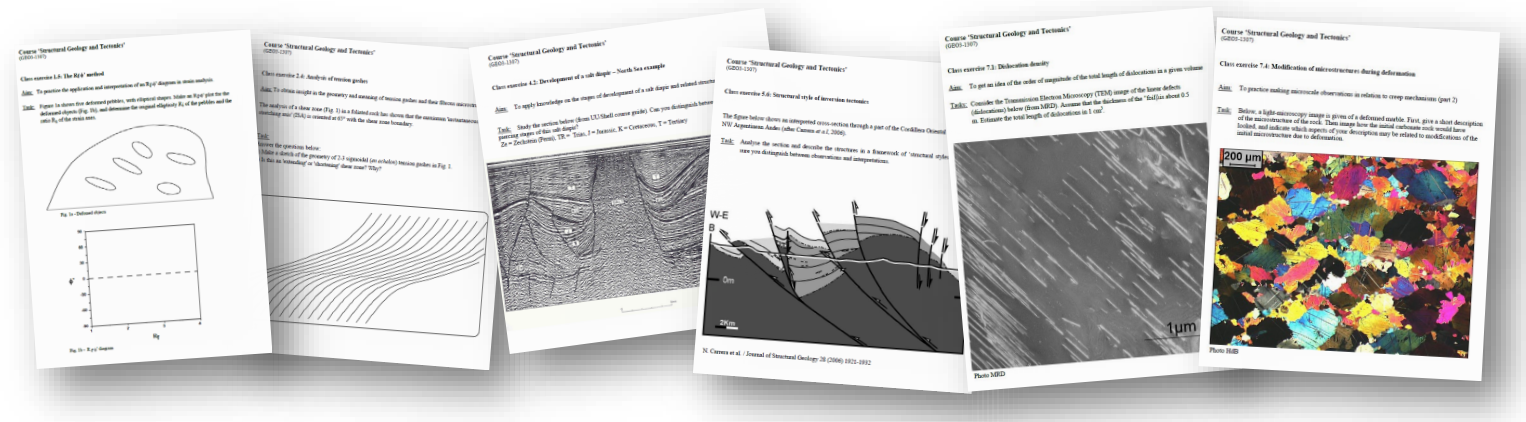
Interactive lecturing in GEO3-1307

- Q & A in the class
- Real time voting using Mentimeter
- Regular breaks with "pictures of the day", from the collection of the lecturer
- **Class exercises** *("enough talking by me, let's do something now")*



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Structural Geology and Tectonics

Class exercises

- Typically 2 per lecture hour
- Well defined aim and task
- Making observations
- Application of a concept, equation, technique
- Time investment 3-10 min/exercise
- Discussion with fellow students encouraged
- Results discussed plenary via Q&A

Class exercises - examples I: Tools for quantification of strain

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Class exercise 1.5: The Rf-ϕ' method

Aim: To practice the application and interpretation of an Rf-ϕ' diagram in strain analysis.

Task: Figure 1a shows five deformed pebbles, with elliptical shapes. Make an Rf-ϕ' plot for the deformed objects (Fig. 1b), and determine the original ellipticity R_i of the pebbles and the ratio R_s of the strain axes.

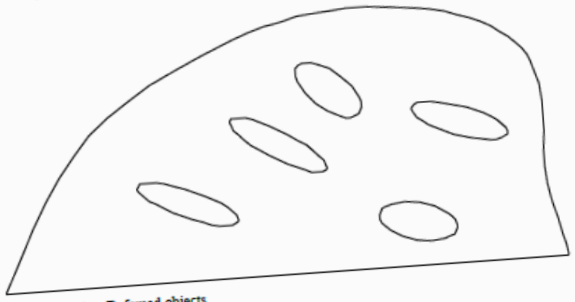

Fig. 1a - Defomed objects

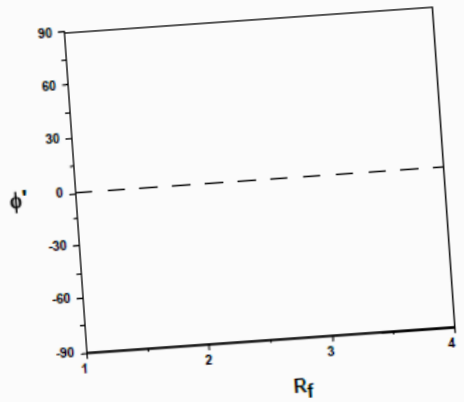

Fig. 1b - Rf ϕ' diagram

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Class exercise 2.4: Analysis of tension gashes

Aim: To obtain insight in the geometry and meaning of tension gashes and their fibrous microstructure

The analysis of a shear zone (Fig. 1) in a foliated rock has shown that the maximum 'instantaneous stretching axis' (ISA) is oriented at 65° with the shear zone boundary.

Task:
Answer the questions below:
a) Make a sketch of the geometry of 2-3 sigmoidal (*en echelon*) tension gashes in Fig. 1.
b) Is this an 'extending' or 'shortening' shear zone? Why?

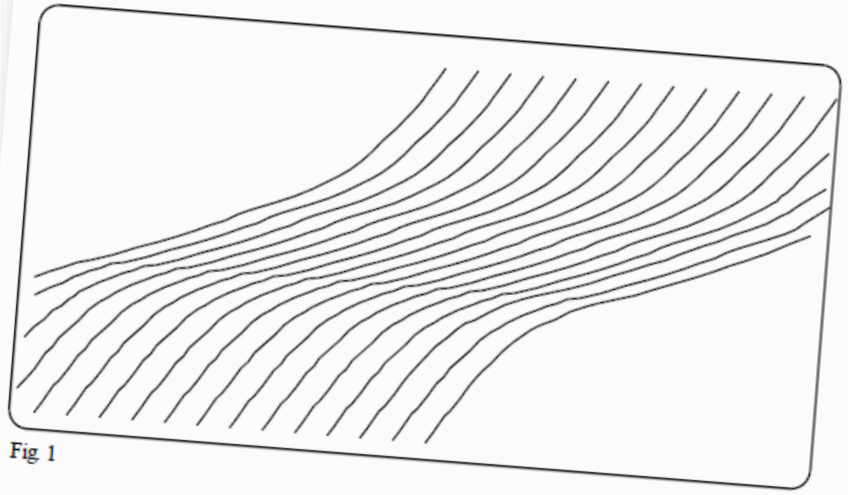

Fig. 1

Class exercises - examples II: Structural styles

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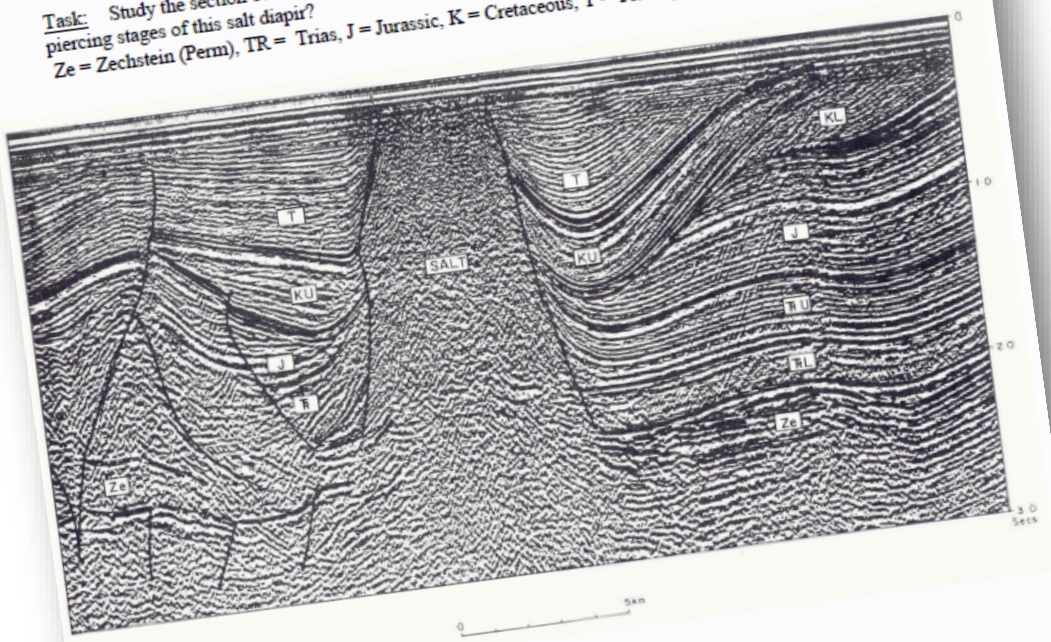
Class exercise 4.2: Development of a salt diapir – North Sea example

Aim: To apply knowledge on the stages of development of a salt diapir and related structures

Task: Study the section below (from UU/Shell course guide). Can you distinguish between the pillowing and piercing stages of this salt diapir?
Ze = Zechstein (Perm), TR = Trias, J = Jurassic, K = Cretaceous, T = Tertiary



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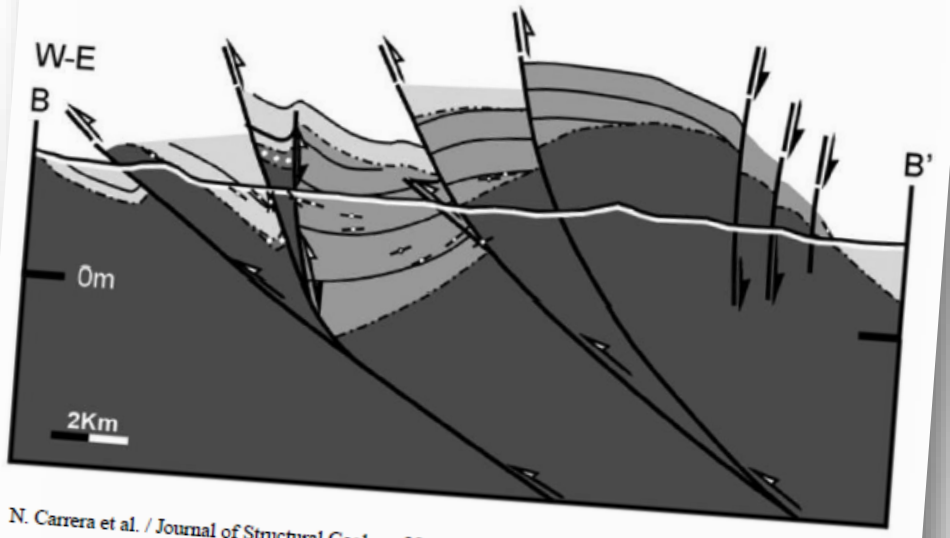
Class exercise 5.6: Structural style of inversion tectonics

The figure below shows an interpreted cross-section through a part of the Cordillera Oriental of the NW Argentinean Andes (after Carrera *et a.l*, 2006).

Task: Analyse the section and describe the structures in a framework of 'structural styles'. Make sure you distinguish between observations and interpretations.



N. Carrera et al. / Journal of Structural Geology 28 (2006) 1921-1932

Class exercises - examples III: Deformation behaviour of rocks

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Class exercise 7.1: Dislocation density

Aim: To get an idea of the order of magnitude of the total length of dislocations in a given volume

Tasks: Consider the Transmission Electron Microscopy (TEM) image of the linear defects (dislocations) below (from MRD). Assume that the thickness of the "foil" is about 0.5 m. Estimate the total length of dislocations in 1 cm^3.

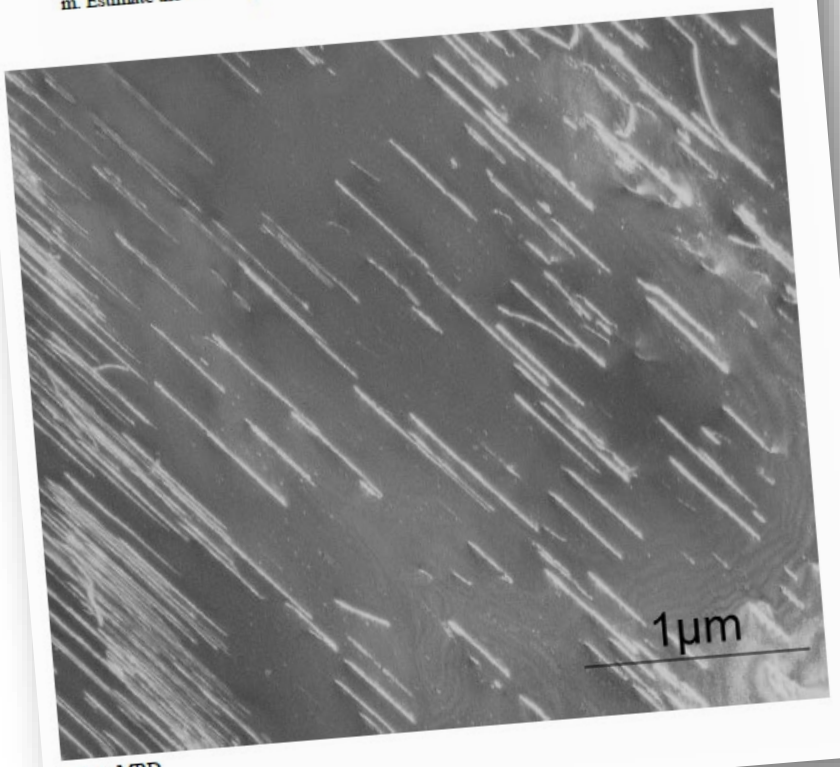

Photo MRD

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Class exercise 7.4: Modification of microstructures during deformation

Aim: To practice making microscale observations in relation to creep mechanisms (part 2)

Task: Below, a light-microscopy image is given of a deformed marble. First, give a short description of the microstructure of the rock. Then image how the initial carbonate rock would have looked, and indicate which aspects of your description may be related to modifications of the initial microstructure due to deformation.

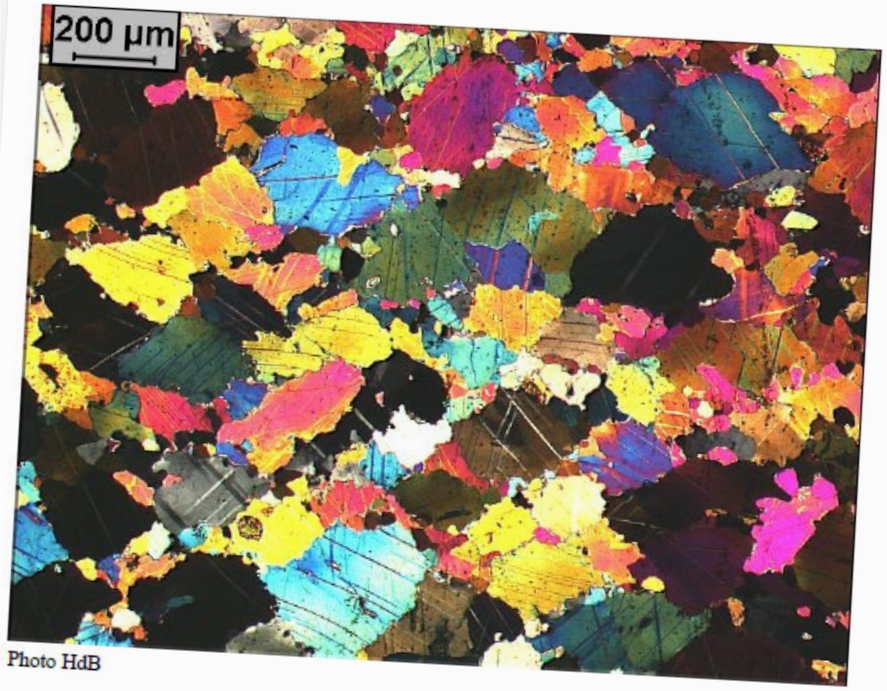

Photo HdB

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Class exercises…

- …bring back the attention of the students (*in case it was lost…*)
- …re-emphasize a topic just discussed (*the power of repe*ating)
- …train distinguishing observation from interpretation (*essential skill*)
- …motivate to come to class (*i.s.o. reading the book bat home*)
- …can be re-used when preparing for exams *(helps learning*)

The students feel engaged!

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Course evaluation:

What are, in your opinion, the three best points of the course?

	2018	2017	2016	2015	2014
1	Practicals	Practicals	Class exercises	Practicals	Didactic quality / enthousiasm
2	Didactic quality / enthousiasm	Class exercises	Didactic quality / enthousiasm	Class exercises	Class exercises
3	Class exercises	Didactic quality / enthousiasm	Practicals	Didactic quality / enthousiasm	Practicals
4	(interactive) lectures	Structure /organisation of course	(interactive) lectures	(interactive) lectures	feedback
5	balanced workload	(interactive) lectures	feedback	Structure /organisation of course	Structure /organisation of course

Top 5 of points mentioned in the yearly course evaluation

(note: no evaluation carried out in 2019, not yet in 2020)

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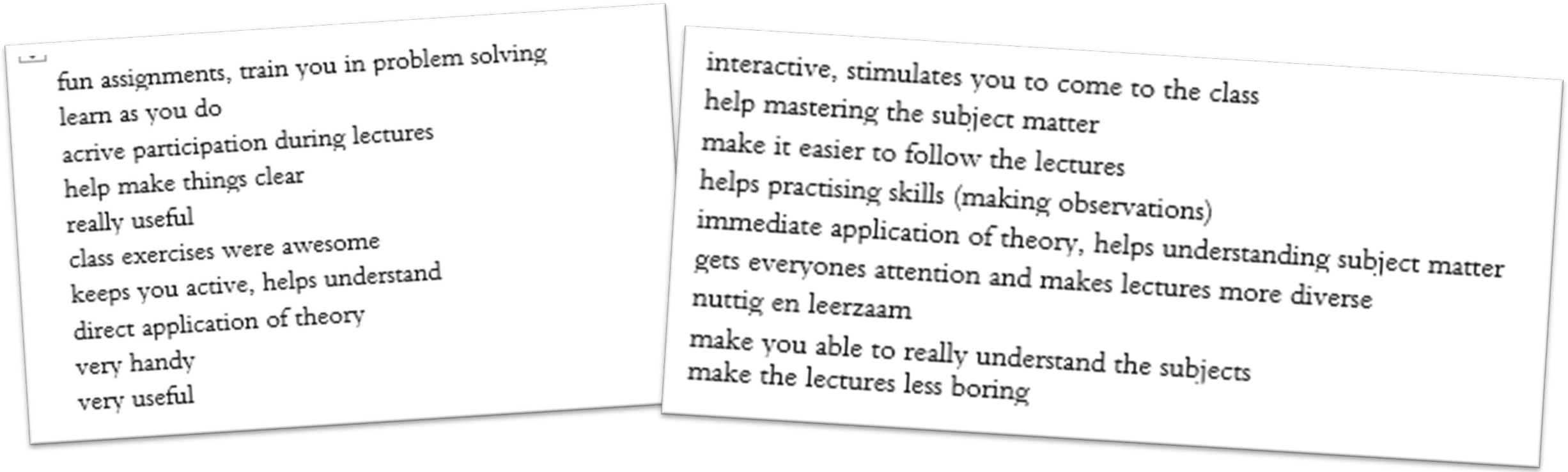
Course evaluation:

Quotes from students re. class exercises:



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Class exercises…

…are easy to implement
…require only limited investment, but result in good yield
…are fun for students and lecturer!

Why not make a shared data base with exercises from which we all can draw?
> EGU focus group Higher Education