Teaching in Iceland

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Teaching in Iceland

- my course — General Relativity with Ziqi
- planning
- remote lecturing
- exam
- things that went particularly well/bad

GR with Ziqi

- 14 weeks x [2 lectures + 1 practice session] (you can get a TA)
- each lecture 90min [40+10+40]
- used *B. Schutz: A First Course in General Relativity* and previous material by Sasha and Javi
- course split in half: first part math (me), second part physics (Ziqi)
- 6 students, all passed the final exam

Planning

Planning

- planning lectures takes a **LOT** of time
- things that have to be done **before** the start:
  - decide on literature and topics
  - coarse schedule/syllabus (to be updated as one goes)
  - fill in all course details online before the registration deadline (course description, exam format, …)
  - …

Planning

Course Description:

This course provides a basic introduction to Einstein's relativity theory: Special relativity, four-vectors and tensors. General relativity, spacetime curvature, the equivalence principle, Einstein's equations, experimental tests within the solar system, gravitational waves, black holes, cosmology.

Teachers: Benjamin Knorr and Ziqi Yan, postdocs at Nordita

Learning Outcomes:

To complete this course the student should be able to:

1. define and explain the equivalence principle and its consequences,
2. state and explain the mathematical connection between spacetime curvature and gravity,
3. state and explain Einstein's field equations,
4. explain the foundations of General Relativity,
5. explain the basic properties of gravitational waves,
6. state and explain the basic properties of black hole,
7. state and explain the basic models of relativistic cosmology,
8. use tensors in calculations,
9. compare solar system measurements to the results of weak field approximations to the field equations.

Planning

Schedule (to be adapted as we go):

	Topics	Teacher
Week 1 Jan 10 Jan 12	Formalities: • overview of course and schedule • info on assignments and evaluation Basics of SR: • fundamental principles • inertial coordinate systems • spacetime diagrams • coordinate transformations • invariance of the interval • key physics results: time dilation, Lorentz contraction • Lorentz transformations	Benjamin
Week 2 Jan 17 Jan 19	Basics of SR: • relativistic addition of velocities Vector analysis in SR: • four-vectors • vector algebra • four-velocity and -momentum • scalar product • energy, momentum and acceleration	Benjamin

Planning

- people have done this before — don’t reinvent the wheel for your first lecturing experience, don’t go too fancy/experimental

- make sure that you have time during your lecturing — consider conferences, other travels, visitors, vacation, regular meetings, …
  You will not do a lot of other things during this time!

- time difference with Iceland: 1-2h (they do **not** change clock)

- ideally, you want to be ahead with preparation 1-2 weeks

- ideally, you digitise your lecture notes for future use

Planning an individual lecture

- plan several hours of prep time per lecture (depends on the topic)
- know and understand the material well
- ask how you want to present the material:
  - why is something important?
  - are there any real world examples?
  - how does it connect to something the students already know?
  - how will it be useful for the rest of the course?

Planning an individual lecture

- start with recap, end with summary, make connections to previous lectures
- for me, 1 lecture ~ 8-10 pages
- spend some time to make good homework sheets — deepen knowledge or show some nice side results

Problem 29: Curvature tensors in general dimensions [8p]

The Riemann tensor can be defined in an arbitrary spacetime dimension d by the same formula,

$$R^{\alpha}{}_{\beta\mu\nu} = \Gamma^{\alpha}{}_{\beta\nu,\mu} - \Gamma^{\alpha}{}_{\beta\mu,\nu} + \Gamma^{\alpha}{}_{\sigma\mu}\Gamma^{\sigma}{}_{\beta\nu} - \Gamma^{\alpha}{}_{\sigma\nu}\Gamma^{\sigma}{}_{\beta\mu}\,, \tag{2}$$

and it has the same symmetries – it is antisymmetric in the first and last pair of indices, it is symmetric under pairwise exchange, and it vanishes when antisymmetrising over the three lower indices.

(a) Determine the number of independent components of the Riemann tensor and the Ricci tensor in an arbitrary dimension $d \geq 2$. [**2p**]

(b) The formulas for the Weyl tensor C and the traceless Ricci tensor S in dimension d read

$$C^{\alpha}{}_{\beta\mu\nu} = R^{\alpha}{}_{\beta\mu\nu} + \frac{2}{d-2} g_{\beta[\mu} R_{\nu]}{}^{\alpha} - \frac{2}{d-2} \delta^{\alpha}{}_{[\mu} R_{\nu]\beta} + \frac{2}{(d-1)(d-2)} R\, \delta^{\alpha}{}_{[\mu} g_{\nu]\beta}\,, \tag{3}$$

$$S_{\mu\nu} = R_{\mu\nu} - \frac{1}{d} R\, g_{\mu\nu}\,. \tag{4}$$

Show that both these tensors are indeed completely traceless, that is, any pairwise contraction of indices vanishes. Hint: $g^{\mu\rho} g_{\rho\nu} = \delta^{\mu}{}_{\nu}$ and thus $g^{\mu\nu} g_{\mu\nu} = \delta^{\mu}{}_{\mu} = d$. [**1p**]

(c) Consider the case $d = 3$ and compare the number of independent components of the Riemann tensor and the Ricci tensor. What does that imply for the Weyl tensor, and thus in turn for the Riemann tensor? [**2p**]

(d) Now consider the case $d = 2$. What can you conclude from the number of independent components of the Riemann and Ricci tensors, that is, what do you need to fix to completely specify curvature in two dimensions? What does that imply for the Weyl tensor and the traceless Ricci tensor, and thus in turn for the Riemann tensor and the Ricci tensor? (For this, it might be useful to use (4) to replace the Ricci tensor in (3) in general d first.) [**2p**]

(e) Is there curvature in $d = 1$? Why (not)? [**1p**]

Remote lecturing

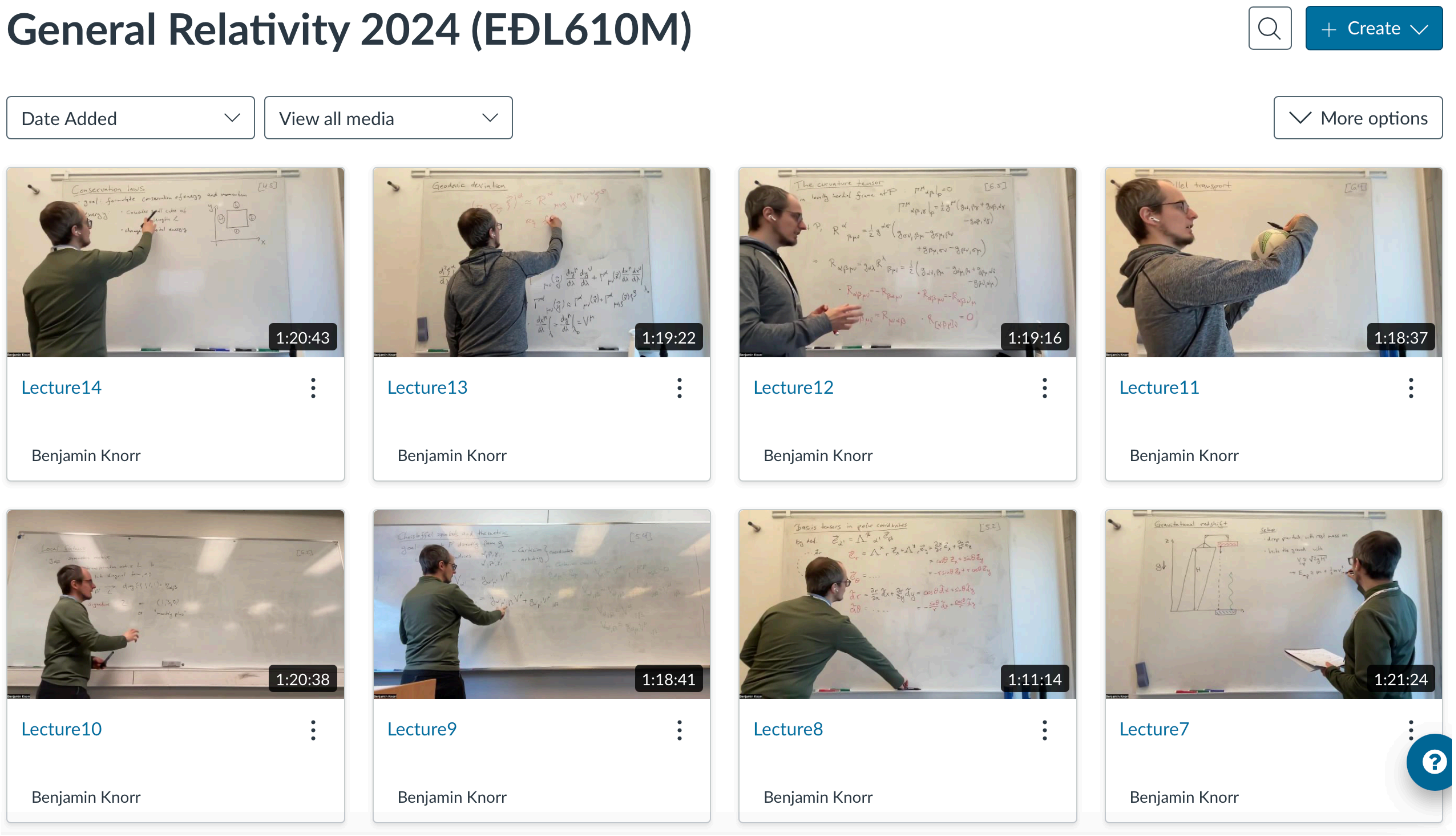
Remote lecturing

- first question to ask: slides or **whiteboard**?
  - even if slides: consider working with tablet and deriving things live
- **record** your lectures
  - can upload to Canvas for students
  - helps you to assess your own teaching
- create a unique zoom room for your lectures

Remote lecturing

- consistent technical setup:
  - optimise lighting (the top-facing light worked better for me to minimise reflections)
  - wear headphones/microphone on body so that you can be heard even if you face the whiteboard
  - if possible use wired internet for stability
  - make sure that you have your charger and enough disk space to record
  - pin your video (learn from my mistake)

Remote lecturing



Remote lecturing

- use colour consistently (I used black for standard text, red for important things, blue for the section in the book, and green in my lecture notes for comments)
- try to speak into the camera as much as possible
- students are hard to activate remotely — you should still try
  - ask regularly if there are questions
  - ask them questions

Exam

Exam

- format of examination must be fixed in advance
  - written or oral? *(oral)*
  - midterm? *(no)*
  - does homework count? *(>40% for admission to exam, but no influence on grade)*

Exam

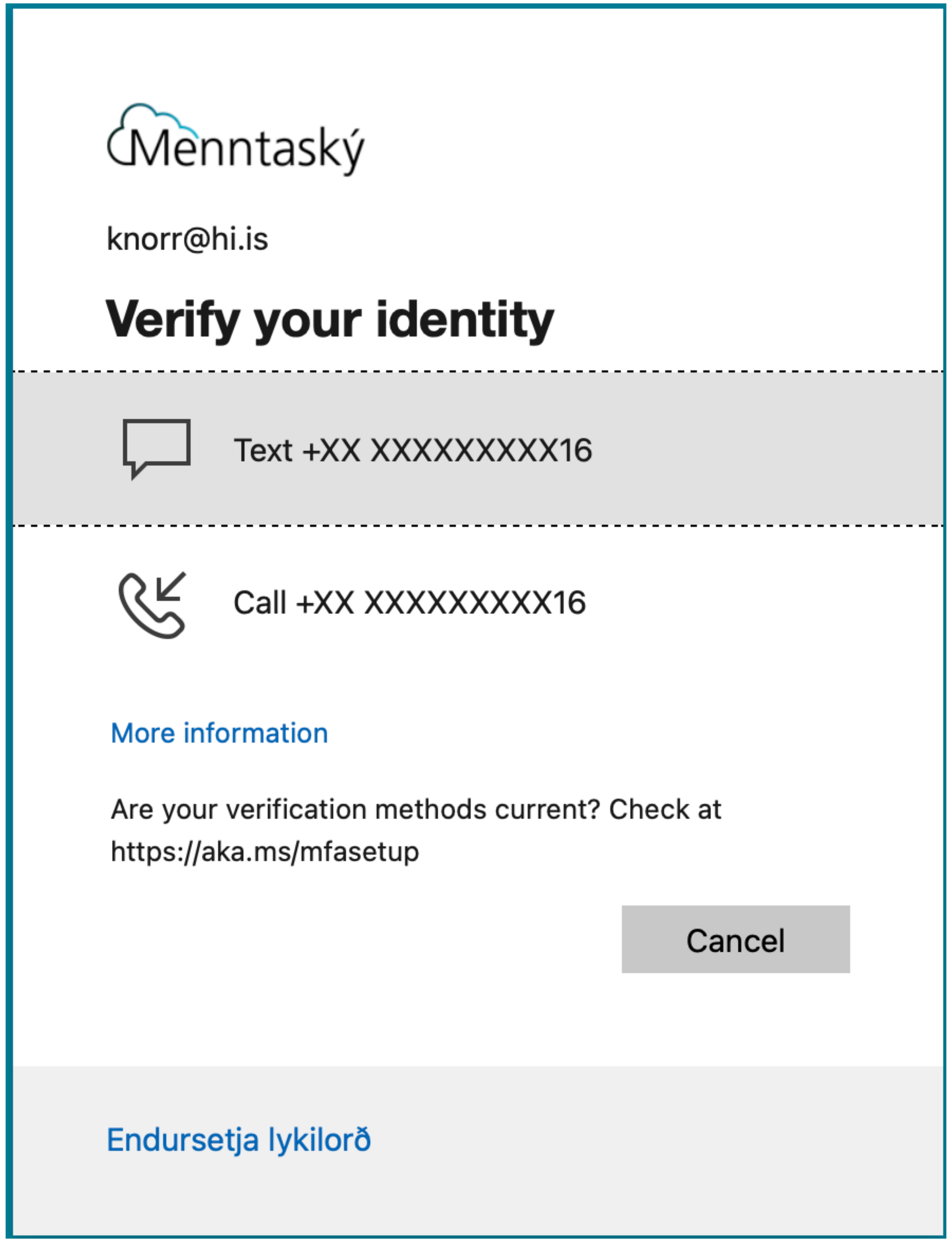
- 30min oral exam
  - 10min on math, 10min on one application (gravitational waves/cosmology/black holes, student picks), 10min on remaining applications and general questions
  - students were asked to present what they know, we probed deeper when they got stuck/went wrong

The good and the bad

The good

- students kept attending
- all students passed the exam first try
- communication/arrangement etc. with people in Iceland worked well, Jesús was always reachable
- there is a new line in my CV and I have a teaching portfolio now

The bad



MS will challenge you for 2FA every n days — this includes your email programme!