AI in University Mathematics Education

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Some Personal Views on Mathematics Education

- Learning mathematics is highly individual. A single explanation to a group can address each student's needs only to a limited extent.
- Lecturers should reflect on the various aspects of mathematical communication and help students become aware of them.
- To really appreciate a mathematical solution, one must first struggle with the problem it solves.
- Mathematics education should not only teach mathematical definitions and results, but also mathematical practices.
- A complex mathematical theory becomes understandable not by specialization, but by generalization.

A Typical Mathematics Course (in Germany)

- **Lectures**: course content is developed step by step and in full detail using a blackboard or slides
- **Exercise Sessions**: tutorials and plenary sessions; discussion of homework, working on in-class exercises, answering questions
- **Problem Sets:** weekly assignments accompanying the lectures; often a mandatory course requirement
- **Lecture Notes**: have a dual role: presenting the mathematical content, anticipating and answering student questions

Challenges

- Lectures and exercises can address individual needs only to a limited extent.
- Talks are not well suited to conveying technical details.
- **The Problem Set Dilemma**: Problem sets become much easier once students have worked through the course material. Yet the pressure to complete them often prevents students from taking the time to do so.
  $\Longrightarrow$ Students may copy solutions from classmates or online sources.
- Lecture notes cannot realistically anticipate every student question. If they did, they would be too long for most students to read.
- Meanwhile, **generative AI** has become an everyday tool.

The Rise of Generative AI – First Implications

- Students increasingly submit AI-generated homework solutions.

  $\Longrightarrow$ Unsupervised written work has become a much less reliable indicator of mathematical understanding.

- Naive use of AI can create an illusion of understanding.

  $\Longrightarrow$ AI may widen existing achievement gaps

- **Professional Mathematical Ethos**: Use every tool available to obtain the best possible result. This also applies to AI – concerning both teaching and research.

- (**Educational caveat**: In education, the learning process is itself part of the desired result.)

Human–AI Collaboration in Teaching

Strengths of Generative AI:

- handling routine tasks at scale
- available at any time; consistently patient and polite
- rapid generation of suggestions and drafts

Strengths of (human) Lecturers:

- selection of topics and methods; experience
- mathematical judgement; responsibility
- building trust and relationships with students

Use Case 1: Instant Feedback

- AI chat assistant to answer students' questions based on lecture notes
- automated or AI-assisted feedback on students' solutions (homework, exams, voluntary exercises)
- interactive feedback dialogues, e.g. to identify and clarify misunderstandings
- lecturers retain responsibility for the feedback process by providing or approving exercises, sample solutions and assessment criteria

Use Case 2: AI Tutors

How it works:

- step-by-step guidance
- Socratic questioning
- adaptive hints rather than complete solutions

Pedagogical aims:

- promoting active engagement, lowering motivational barriers
- develop mathematical practices, such as problem solving and questioning arguments

Note:

- AI support should be gradually reduced as students gain competence
- AI tutors are no substitute for working through problems independently

Use Case 3: Data-Driven Teaching and Learning

General principle:

- AI identifies patterns in student data
- provides feedback on learning progress and course design

Applications:

- individualized long-term feedback for students (e.g. on repeated errors across homework submissions)
- aggregated feedback for lecturers, such as performance on individual homework problems or frequently asked questions

A Proposed Synthesis of AI and Traditional Teaching

- **Lectures**: provide an overview and explain the main ideas; select technical details carefully; aim for a good level of mathematical generality
- **Lecture Notes**: include complete proofs; don't try to anticipate students' questions; an AI Tutor to guide students through the details and provide additional examples
- **Exercise Sessions**: focus on active and collaborative work, including discussion, comparison of approaches, and solving problems together
- **Problem Sets**: easy exercises + AI Tutor to prepare for exercise sessions; more challenging exercises for in-class work; automated feedback for homework problems

Criteria for Successful AI-Enhanced Course Design

- Use in-person time for active and collaborative problem solving.
- Students should understand the purpose of the AI tools and how they can *concretely* benefit from them.
- AI tutors should gradually reduce their support as students gain competence.
- Keep the overall student workload realistic.