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Flipped classroom, peer instruction, and just-in-time teaching in mechanics lectures: How to make students study during the semester

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We all know this problem from teaching large undergraduate classes. Our typical format of lecturing to huge student audiences and solving example problems in exercise sessions on the board has demonstrably limited effectiveness. Moreover, it often promotes that students aim to absorb information during the semester and concentrate all their studying efforts right before the exam (with the sole objective of passing the exam). Such learning is ineffective and little sustainable. What is missing is *time on task* by the students during the semester. Therefore, a key question has been: how can we make sure that our students spend quality time during the semester on actively developing a fundamental understanding as well as analytical and/or computational problem solving skills?

We will discuss a number of tools that have been deployed and are being continuously developed in some of the undergraduate mechanics courses in Mechanical Engineering at ETH Zurich and HTW Dresden, including basic mechanics classes as well as electives in computational mechanics. Key are concepts such as Flipped Classroom, Peer instruction and just-in-time teaching. The idea of the Flipped Classroom is to provide the learning material before the lecture, so that the time in the lecture is used for practical application and discussion. To this end, short video sequences are provided and online self-tests are offered to check students' understanding. Whether or not Flipped Classroom or on-site lectures are preferred, peer instruction and just-in-time teaching can then be used during the quality-time students spend in the lecture halls. In addition, we show further specific activation elements such as challenging student polls (ideally combined with an experiment or application), weekly online learning elements as homework (using gamification for advanced participation), and computational projects (translating theoretical concepts into code). Aside from making sure that students spend time on the subject, such elements also provide timely feedback to the students on their individual learning success as well as to the instructor on the collective performance. Our experience and statistics evaluation in terms of Scholarship of Teaching and Learning show that an effective combination of didactical concepts significantly enhances student activity. Furthermore, even little incentives are sufficient to maintain student participation with a positive impact on sustainable learning and exam outcomes.