ETH zürich

Learning and Teaching Journal Special Edition

Proceedings of the
Learning and Teaching Fair 2018

Apps / Mobile
Learning

Audiovisual
Media

Authentic
Assessment

Competence-Oriented
Learning

Engaging with Simulation
and Gaming

Entrepreneurship and
Transdisciplinarity

Flipped
Classroom

Global
Citizenship

Interactive Learning
(Collaboration)

Non-Disciplinary
Competences

Peer
Review

Research-Oriented
Learning

About the Learning and Teaching Journal

The Learning and Teaching Journal is a multi-disciplinary journal issued every six months by the Educational Development and Technology (LET) unit at ETH Zurich. It provides a platform for the discussion of teaching and learning in higher education, particularly in the STEM disciplines, and for the sharing of systematic observations and reflections regarding discipline-specific teaching and learning. The Journal boosts and extends ETH Zurich's body of knowledge on teaching and learning.

Key areas addressed by the Journal include:
- Education in specific disciplines and/or in the STEM area
- Scholarly discussion of teaching and learning in individual courses, study programmes and departments
- Academic or disciplinary culture and teaching approaches

About this issue

This issue of the Learning and Teaching Journal is a special edition which focuses on projects presented at the first "Learning and Teaching Fair 2018", to be held on 14 November 2018 at ETH Zurich. The ETH Learning and Teaching Fair, to be held annually from 2018 onwards, will showcase the richness and diversity of teaching and learning at ETH by presenting a wide range of teaching and learning projects contributed by both ETH teaching staff and students. The intention of the Fair is to become an inspiring vehicle for discussion and feedback on the topic of student learning for the entire ETH teaching and learning community.

The first ETH Learning and Teaching Fair also marks the launch of the Learning and Teaching Journal. This open online journal will provide a platform for analysis, review and discussion of teaching and learning in ETH disciplines, to further the aim of educating students to be bothhighly qualified professionals and responsible members of society. While the platform will primarily feature ETH authors, their contributions will be available outside the institution – bolstering ETH's role as a world leader in research and teaching. Find the journal online at
www.learningteaching.ethz.ch.

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Æther: A research-and-writing workshop in Science and Technology Studies

The aim of this teaching project is to design and develop an innovative, internet-based science magazine in the field of Science and Technology Studies (STS): www.aether.ethz.ch. Students have the opportunity to critically engage with the future of digital scientific publishing, both conceptually and practically.

The project combines a historical and theoretical approach to scientific publishing with the implementation of an actual, digital publication. The aim of the project is to design and develop an innovative, internet-based science magazine in the field of Science and Technology Studies (STS). By conceptualising and developing a prototype magazine students will be given the opportunity to learn about, and engage with, current debates about the future of scientific publishing, while simultaneously shaping it pro-actively. In the light of recent discussions concerning open access, the digital humanities, and so on, how can we deploy digital technologies more purposefully and attractively to communicate our research results to the wider public?

Success factors

- The collaborative work toward a product (= a publication) served as a major motivational incentive for students.
- Regular feedback sessions and teamwork in the process of designing, researching and editing the publication helped to engage students and ensure the quality of the results.
- Intensive, individual supervision of students / contact-hours.

Innovative elements

The project systematically integrated research, teaching and science communications in the humanities by way of developing a joint "product" from scratch – including the development of an online/print publication platform, of individual research projects, and the writing and editing of research articles.

Room for improvement

The teaching-format is demanding, both for students and teachers; there's room for improvement as regards integrating this kind of seminar into the profiles of the various degree programmes. The "last mile" (after the end of the semester) in particular proved a little difficult to align with students' schedules and expectations (re workload).

Opinion of students

The feedback we've received was overwhelmingly positive. Students particularly emphasized the following items:

- Mix of regular contact-hours and group-work / feedback
- A concrete, attractive objective (= a joint publication), accompanied by a rich variety of seminar activities, including fieldtrips, presentations by and discussions with external guests and experts.
- The seminar enabled interdisciplinary / intellectual exchange as well as enabled students to bring their own expertise to the table.

Tips for lecturers

- Encourage students to take on responsibilities (e.g. by delegating editorial tasks, mutual feedback on writing, etc.)
- The balance of systematic group-work and (intensive) individual supervision was a significant factor in successfully completing the project.
- Co-teaching is essential for this type of seminar.

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A model for modeling

Our teaching project aims to build a more coherent curriculum for modeling. We help rationalize learning objectives for modeling between courses, and follow student skills' development with a novel concept inventory.

We are interviewing lecturers and students to create an evidence-based modeling curriculum for environmental sciences students at ETH. To monitor our progress we are building and testing a modeling competence inventory (MCI) to track students' progress.

Modelling is a technique used in almost every field of natural science and many fields in social science, and our students' academic and professional work requires that they understand models even if they do not use them. Modelling uses multiple skills, including epistemology, programming, mathematics, domain knowledge, and common sense. Teaching this requires a curriculum-wide plan, and coordination between many lecturers and professors.

Knowing which of students' skills need improvement, and when, requires a systematic assessment of students' modeling competencies. Competence inventories use a combination of true and plausible false answers (distractors) to tease out gaps in students understanding. Competence inventories have been developed for several practical scientific activities but not yet for abstract activities like modeling. We describe our efforts using crowd-sourced misconceptions, and present the MCI that we have developed for field-testing.

The interviews with lecturers and professors, and subsequent discussion in a workshop, have already pointed to aspects of the environmental sciences bachelor programme that can be improved. After introducing the MCI to a large body of students, we will use the results from the MCI to better integrate the courses that teach modeling into a coherent curriculum, reduce unneeded repetition and increasing time spent on skills that need more development for practical use.

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An interdisciplinary and application-oriented approach to teach microfluidics for microbial ecology

Our interdisciplinary course directed at a heterogeneous group of doctoral student participants aimed to help students identify the experimental advantages and requirements of microfluidics and learn how to design and perform an experiment in view of their own project.

The course Microfluidics for microbial ecology is a 5-day course, where students can learn the basics of microfluidic technology and sample a range of applications in microbial ecology. Microfluidics is a relatively novel technique with broad applications and an interdisciplinary basis. The course is designed for Master and PhD students, who are interested in applying microfluidics to their experimental activity and have very different backgrounds, ranging from microbiology to environmental engineering. Given this teaching context, the first objective of the course is to provide the students with a basic theoretical foundation of all the critical components involved in microfluidic experiments for microbiology. This knowledge is the basis for the second objective: to understand the experimental advantages and requirements of microfluidics and learn how to design and perform an experiment.

Student learning was promoted through two active learning activities, aimed at teaching how to apply and adapt the technology to very diverse experimental realities. The first activity was the development of an individual experiment in microfluidics: students were guided during the theoretical lectures to apply each module to their personalized application and discuss it in small groups. This activity was designed to help student linking the different theoretical topics together while personalizing the information for better learning. The second was a group experimental activity, in which students had to set up, perform, and present a microfluidic experiment. The experiments were chosen to show specific advantages and disadvantages of microfluidics and the final presentation of the results was aimed at further promote collective critical evaluation.

The individual project and the group presentation of the experimental results allowed us to assess the benefits of the application-oriented approach in meeting the learning objectives. In addition, the students' provided information on their training prior to taking the course and completed a survey at the end which provided information on their level of confidence on each theoretical module before and after the course. Altogether, the students' satisfaction was high and reflected their level of engagement in the course.

The application-oriented approach with significant experimental activities and in-class discussions, in our opinion, is well suited to promote students learning of a technology like microfluidics. Given the multidisciplinary teaching context, it fostered the creation of a common conceptual ground and promoted discussion between students and with instructors. This gave students from diverse backgrounds opportunity and motivation to remedy their individual gaps in understanding

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OMLETH: A multimedia guide for field trips

OMLETH is a map-based learning platform, used in formal and informal educational institutions. It features educational multimedia field trips that allow authentic, location-based mobile learning.

Introduction
Many learning contents and processes of study programs in architecture, civil engineering, and natural sciences at ETH Zurich are strongly related to environmental phenomena. However, teaching in these study programs is mostly still limited to lecture halls or flipped classrooms and decoupled from the real world outdoors. Beames et al. (2012) argue that learning outdoors brings curricula alive, helps students to understand the authentic environment and related issues, and that it encourages physical activity. The ubiquity of context-aware mobile phones enables the design of suitable contemporary learning environments which consist of mobile education trails outdoors in the real world. The learner becomes mobile and is supposed to connect the surroundings with educational content through interactive multimedia triggered on mobile location-aware apps. This type of mobile learning is often called location-based mobile learning (LBML) (Brown et al., 2010).

Popular learning management systems are still not able to store geo-located contents, though professional technologies for handling and visualizing such content are available (geographic information systems, GIS, see Goodchild, 2011). The mobile web app OMLETH ("Ortsbezogenes Mobiles Lernen an der ETH"), funded through the Innovedum funds of ETH Zurich, bridges the gap between GIS technologies and learning management by enabling the assignment of learning contents to places (Sailer et al., 2015).

Teaching concept

The OMLETH user interface uses powerful geo information technologies[1], including interactive web map services that can show satellite, street, or topographic maps. Lecturers can easily create the content and its geospatial grounding (i.e, polygons) using the OMLETH map interface in a standard web browser. The technological capabilities offered by OMLETH leave many design choices to the lecturer. However, to enrich the genuine experience, a powerful story with a well-constructed plot structure similar to movies is required. The learning material may be represented as text, image, audio, video, or links to web resources like augmented reality applications. The trail's stations can be configured as inquiries to ask students to upload text documentations, pictures, voice, or video recordings, with the goal of processing observations and making students reflect. Questionnaire-based assessments focus on analyzing and evaluating the local phenomena and letting students mutually reflect and argue. Online communication channels can be integrated and allow students to get feedback and exchange with the teacher or peers from everywhere. The above list illustrates that with OMLETH, teaching becomes very different and customizable to the local surrounding and context.

Students perform the education trails individually or in groups with an HTML5-enabled mobile client. Navigation and access to interactive multimedia content are activated depending on the GPS position of the user's device. Students must be on-site and enter the polygon associated with the content to gain access to a particular learning activity. OMLETH collects users' movement data during their discoveries and observations. These datasets enable lecturers to have control about students' movement progress, to assist w.r.t. navigation and safety issues, and to support instructional scaffolding (Sailer et al., 2016). Further, the students can review these datasets during a de-briefing session back in the classroom. All data records of OMLETH are encoded using HTTPS during transfer. This ensures security and privacy during the transmission.

OMLETH in practice: results

Explorative studies have shown that lecturers usually allocate the different tasks on an OMLETH education trail close to each other to optimize time and the flow of learning. The trails' missions were mostly initiated with a short story and a problem statement

1) https://developers.arcgis.com/

including the learning goals. Next, tasks were often composed as group work. Some teachers chose rather open tasks to foster learners' agency (Suárez et al., 2018), others created more formative assessments or short assignments with popular web forms. Observations are mostly documented by text and photos. And finally, in-depth information was sometimes included using links to special services or external learning management systems.

A large empirical study about student achievement in secondary schools has shown that LBML with OMLETH improves the cognitive performance in written exams. The trails demand a strong commitment and the willingness of an active confrontation within the context. Learners with intrinsic subject motivation are reinforced, whereas learners without basic motivation are reluctant despite using mobile phones. The result of the qualitative evaluation shows that it depends on the situation and the design of the trail: drama-like procedures (exciting hooks followed by the problem statements, embedded in a well-constructed story with authentic tasks) as well as tasks with a high degree of self-determination (competence, autonomy and affiliation) are important for the success of LBML. Some of the participating ETH students argue that new, rich or complex theories should still be instructed in classrooms and not in long text messages on small displays. Long-term evaluations have shown positive effects on cognitive performance.

Lessons learnt

More than 100 education trails with student groups in higher education, middle school and informal settings have been carried out with OMLETH. Most of the users were novices in using their smartphones for LBML. The technical knowledge about the configuration of sensors and the use of interactive map layers were sometimes lacking and had to be introduced by the instructors.

In formal education, OMLETH has been integrated into regular lessons in many ways, such as for anchored instruction, or for transferring the gained knowledge with formative or summative assessments. Experiments show that OMLETH plays a certain role in student achievements with slightly improved test scores. However, students' self-assessment of cognitive performance is often less positive. Lecturers guess this attitude is influenced by possible biases of their educational socialisation. Further, some students argue that educational trails consume a lot of time, and that traditional learning by lecture hall instruction is more effective. They prefer to learn the concepts and theories in classroom lectures before, and only afterwards apply this knowledge in an LBML trail. In the case of formative assessments, they appreciate the possibility of getting feedback and asking questions at any time. However, the other part of students strongly welcomes self-regulated LBML and is aware of the positive effects of self-regulated outdoor trails in both, the short and long terms.

The main lesson learned w.r.t. teachers is related to the skills needed for creating exciting education trails. In addition to technical experience and geospatial abilities, teachers also need didactical experience in creating authentic stories and meaningful tasks that are well adapted to the students' prior knowledge. Furthermore, an education trail for LBML should always finish with a classroom debriefing session to clarify open questions and to avoid failures or subjective theories. Finally, lecturers and most of the students conclude that the action-oriented and multi-sensory learning approach, as well as the long-term learning outcome create benefit for learners and make LBML sustainable.

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Bringing the factory to the students: Enriching teaching cases with Virtual Reality

Our project “Case VR” brings the factory into the classroom of production and operations management courses. By using virtual reality we enhance the case method for teaching socio-technical phenomena.

An operations management class should equip students with a realistic understanding of the operations of a factory and ways how these can be made more efficient. However, organizing factory visits for an entire class of students requires significant resources. At the same time, the common alternative of text-based case studies does not allow students to receive an inside-view of how a factory works. As a solution to this, we propose the use of virtual reality (VR) to bring the factory to the students. We present the results of a pilot study of a VR enhanced teaching case that we used in the 2018 spring semester course “Global Operations Strategy”.

For our teaching case, we teamed up with the ABB Group that offers VR environments of some of their factories located in Switzerland, Germany and Finland. We introduced these VR environments as case material for our three-part, graded case study which the students were asked to solve in groups of three to four. We also scheduled a guest lecture of ABB speakers to provide the students additional background information. In the first part of the case study, we encouraged the students to use the VR environment to collect information about the production processes in specific factory locations. In the second part, students were asked to observe and analyze the production layout, internal logistics and general productivity of the sites. In the third part, students used the VR environments to compare factories in order to suggest a multi-site production improvement program. Each case part was concluded with presentations of student solutions and class discussion.

To evaluate the effects of a VR enriched case study on student learning, we administered a survey and conducted focus group discussions. The survey, which was taken by 65% of the students, provided a general picture. More in-depth insights were obtained from the focus group discussions which were directed, recorded and coded by Karin Brown from the LET.

We learned that indeed, VR enhanced case studies can complement operations management teaching but its implementation is not without challenges. Our results suggest that VR allows students to immerse into factory environment and that the use of new technology has potential to boost student motivation. Due to the low cost of basic virtual reality glasses, classes anywhere in the world can in the future adopt VR case studies. Furthermore, also related engineering and management classes can profit from similar approaches.

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Coffee Lectures – A new format for teaching information and communication technology skills

In natural sciences, digital tools for information management are essential but formats for teaching them were missing. Coffee Lectures provide such a format, which is now successfully adopted by 50 institutions Europe-wide.

Since scientific data and information became digital, a steadily increasing number of databases and tools for the retrieval, analysis and management of information has emerged, especially in chemistry and life sciences. Using them efficiently and effectively during the research process is a competitive advantage and helps to stay ahead of the field. However, scientific databases and tools are generally underutilized and often not known. This is also due to the fact that so far, a suitable format for teaching and learning digital literacy was missing, as traditional course formats do not apply. At the Chemistry | Biology | Pharmacy Information Center (ICBP) at ETH Zurich, we have, therefore, developed such a format. Coffee Lectures allow students and researchers to learn about new and existing scientific databases and tools, to know about possible use cases and to critically judge when and which database or tool should be applied for a particular research question.

The curriculum we build consists of more than 60 databases, tools and concepts we think students and researchers should know about. We present those frequently in short and problem-based Coffee Lectures in an informal setting around noon, with free coffee and tea. Coffee Lectures are only 10 minutes long and no registration is required. Each Coffee Lecture presents a typical problem most researchers in a field are familiar with and shows the solution, i.e., a database, web service, app, or a concept that can be utilized. Coffee Lectures are preferably presented in an entertaining style.

At ICBP we have launched the Coffee Lectures in December 2013 as three-week series, with nine different Coffee Lectures per series. Software, tools, or databases are shown live with real examples. All attendees are provided with a Coffee Lecture Card, where basic information and the main features are summarized. A Coffee Lecture Card Album that we also provide allows to keep track of Coffee Lectures one already attended – or of those that one missed out.

Meanwhile, about 50 institutions, mostly university libraries in Germany, Switzerland, and Austria have successfully adopted the format. A first user group meeting was held at the Karlsruhe Institute of Technology in April 2018, and a website for the Coffee Lecture User Community (www.blogs.ethz.ch/coffeelectures) has been set up.

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Communication to the non-scientific public using the Wikipedia Free Encyclopedia

We have designed a reading seminar to practice the communication of published scientific results 1) orally to scientific peers and 2) to the wider public, using creation of Wikipedia pages.

Communication is very important in academia. Presenting and confronting ideas allows transferring and improving knowledge within the community. Scientific publications and participations to scientific meetings are keys in an academic career. The importance of communication to non-scientific public is frequently underestimated in academia, or delegated to communication specialists (e.g. museum). We have designed a reading seminar to learn and practice oral communication of published scientific results to scientific peers and written communication to the wide public using the multilingual, web-based, Wikipedia free Encyclopedia. The latter is widely used by people from different audience from everywhere around the world. It is openly editable, allowing very quick updates. We share here our teaching experience with an Earth Sciences class, based on class assessments and students evaluations.

During the second half of the 2017 Fall semester at ETH Zürich, the teacher has taught a 1 ECTS M.Sc. level reading seminar on the broad topic of Heat and Mass Transfers in Magmatology. Three first semester and six third semester M.Sc. students have attended the course. All students had a B.Sc. degree in Earth Sciences, but seven where registered in the Institute of Geochemistry and Petrology Institute and two in the Institute of Geophysic.

By groups of two, students have read a scientific article, presented it orally to classmates and answered to questions from the peers. During the last two classes, students have edited and created Wikipedia free Encyclopedia pages in relation to their article's topic. Students really enjoyed creating a Wikipedia page, even if they didn't use it or didn't trust the Wikipedia content. They had little experience with communication to a non-scientific public and thought this exercise was challenging.

Evaluations show that writing about a scientific paper in a Wikipedia page is a less efficient learning technique than reading a scientific article, presenting it orally or discussing it in a group. However, it certainly contributes to better memorise important information and it is an efficient way to practice writing and public and scientific communication skills. As an interesting side effect for the scientific part, it has the potential to reach a wide international community. With this contribution, we wish to encourage colleagues in Earth Sciences and beyond to teach their students how to communicate science to scientific peers and non-scientific public.

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Digital moviemaking in student degree theses

To train science communication skills, students had to present their results as movies instead of written degree theses. Student motivation, self-initiative and efforts were much higher than in classical project formats.

Introduction

We are confronted by multimedia every day. Since around 1997, the time we spend on electronic media surpasses the amount of time we spend in face to face interactions. With today's flood of information, gaining the consumer's attention and conveying information has become ever more challenging and competitive. In this respect, movies and images perform much better than written words: Texts are processed by our working memory, which can hold only seven objects at a time; visual information, in contrast, goes directly into our long-term memory and can be memorized in much larger quantities. Current university students not only consume multimedia content, they increasingly appear as producers, mostly on social media platforms. So it is not surprising that young people are nowadays called 'digital natives'. However, despite their inherent aptitude with new media formats, university students rarely have the opportunity to apply their experience in a more academic setting. They are most often asked to hand in research papers, which thereafter end up in the supervisor's drawer without having any further impact. This stands in stark contrast with efforts such as ETH's Critical Thinking initiative, which amongst others, aims at fostering student competence in sharing knowledge with peers and society. In the autumn semester of

2017, ETH historian Bernhard Schär and the author introduced a multimedia component to their course "Historical Collections in Context: Putting Butterflies, Stones, and Orchids on Film". ETH Zurich holds scientifically outstanding zoological, botanical and geological collections with millions of specimens as well as accompanying letters, field books, photos and drawings from the past centuries. This cultural and scientific heritage provides a rich resource for student research. The multimedia component of the seminar was for students to carry out their own research projects on a topic in the history of science and to create a movie to present their findings.

Teaching approach

The learning objectives for the multimedia component were threefold. First, students would learn to perform independent scientific analyses in a relevant area. Second, students would develop skills in the use of current multimedia technologies. And last and most importantly, students would learn how to break down complex subjects into understandable stories and present them in a concise and entertaining short film no longer than 2-3 minutes. The course lasted for fourteen weeks with two lessons in class per week and accounted for three ECTS credits. Over the fourteen weeks, students were introduced into the different fields of the course:

- the ETH Multimedia Services team gave training on the technical aspects of movie making
- in order to familiarize themselves with the subject matter of the course and to identify research questions for the following movie projects, the students visited the Zurich Herbaria, ETH's Earth Science Collections and ETH's Entomological Collection
- in class, the students discussed history of science papers, thereby learning how to analyze questions in the history of science
- outside class, students read history of science articles on their own and composed short papers on a biweekly basis.

In the last four weeks of the semester, the students worked on their own movie projects in groups of two. Two months later at the end of the semester break, the movies were handed in. In a small closing ceremony followed by an apero, the films were screened and jointly discussed.

Results

Initially eleven students enrolled for the class, seven started and six finished by completing the movie project. As subjects, the students chose the history of the ETH Entomological Collection, the expedition to Iran by the Swiss geologist Arnold Heim, and the botanical field trip to Angola by the Swiss couple Hans Ernst Hess and Esther Hess-Wyss. In addition to the movies, students submitted documents with associated metadata such as primary and secondary references or software products and multimedia data used. From a technical viewpoint, all movies were excellently produced. Students were offered Adobe Premiere by ETH, but most of them used additional software products such as iMovie, Pro Tools or Garageband on their own. For the shooting of the films, most heavily used were visualizers, which allowed to record sequences of photos or other documents, to add post-it notes, write titles or draw sketches. Furthermore, indoor footage was taken in collection facilities with professional cameras and smartphones. Students put their materials on screen in very creative ways. For example, cameras zoomed in on images; photos flowed into each other; and a hand leafed through a field book or drew a sketch. Nice effects were produced as well from animated PowerPoint slides. Whereas voice-over narrations were added to all three movies, a soundtrack was used only in two of the films. In general, students acted very independently and required little supervision from the lecturers. Each of the movies was highly enjoyable to watch and very understandable. The students did not limit themselves to presenting lists of facts, but nicely crafted their findings into multimedia stories, which involved the audience with humorous details and moving moments. Although some of the films exceeded the prescribed duration (they lasted 2'30", 7'30" and 8'07" respectively), none of them was verbose or tedious. The shortest one was fast cut and presented its statements in a trendy style but was rather superficial in terms of historical statements. The longer ones excelled in substantive analyses and relevance while still being entertaining. One of the failings was that students occasionally overlooked copyright regulations, which then had to be sorted out in a tedious process at the end of the seminar.

Discussion

Producing movies as student degree theses proved to work excellently in a university teaching environment. The analyses were in most cases thorough, the films were cleverly crafted and the findings were presented in an entertaining and concise way. In comparison with classical written theses, students exhibited markedly greater motivation in a multimedia setting and invested more time on their projects. This may be partly explained by the media itself which allows for more creativity and engages multiple senses whereas written texts - especially academic papers - may be seen as more formalized and dry. In addition, written theses are hardly ever read or discussed in public, in stark contrast with films. Public performances of the students' movies

1) https://www.kulturerbe.ethz.ch/index.php/naturhistorische-sammlungen-erzaehlen-geschichten/?lang=en
2) https://blogs.ethz.ch/digital-collections/2018/06/04/collections-in-context-globale-vernetzungen-auf-film/

were highly anticipated and they were shown on several occasions. First, they were presented to the whole class and the curators in a final ceremony. Afterwards, the films were shown on stage at the event "Cultural Heritage at ETH Zurich", followed by a panel discussion with the students, curators and media professionals[1]. Some of the movies were discussed in a blogpost[2], and some will be displayed in an infinite loop on large screens in several university buildings. And last but not least, some of them have been uploaded to YouTube and are thus visible to the whole world[3,4]. By showing their work to a larger audience (including their peers!), students realize that their efforts matter and are appreciated. Keeping this in mind, universities may want to consider creating appropriate multimedia platforms for student multimedia contributions if they ever plan to establish movie making in classes. There are some caveats to movie projects, which require a mention too. Whereas searching for specific information in texts is relatively easy both for human readers and even more so for computers, targeted information retrieval proves incomparably more difficult in movies – both for human viewers (endless scrolling) and more so for computers, which cannot understand speech nor interpret the footage correctly. For supervisors of student projects, written documents are therefore better suited as information repositories than films. Another issue might be the shallower depth of substantive analysis in movie projects. As students spend most of their time on the technical aspects of creating films, the analysis of the subject matter itself may lag behind. In the current course, this effect was attenuated since students invested much more effort on their movies projects in comparison with students from previous courses with written term papers.

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Enhanced Food Chemistry Lab: Interactive, social and virtual

Improving general lab skills as well as report writing skills during the food chemistry lab course by using interactive videos, lab simulations as well as a peer-review tasks for students.

There are some fundamental skills that students should thoroughly acquire from the very beginning of their studies of working in the laboratory, such as lab safety, selection of reasonable equipment for an experiment to ensure quality of results, waste management, writing reports, drawing graphs and tables, etc. According to our experience in the Laboratory Course in Food Chemistry, the time in the introductory lecture is not sufficient. Because of the setting, important information and concepts are only mentioned once. To facilitate the learning and adaptation process and make it more active, we decided to offer the students interactive study material for independent studying before and during the laboratory work. With the interactive videos, virtual laboratories and peer review tasks, the students actively study and prepare for the laboratory courses already before the contact hours and test their skills to evaluate the learning process. This allows for the time during the contact hours to be more efficiently used for the substance knowledge and skills. The virtual laboratories allow the students to perform experiments virtually that are not possible in the real world due to security, time and/or money concerns. With these interventions we hope to increase the overall satisfaction on both sides, for students as well as for assistants and lecturers.

To investigate the effects of our teaching project on improvement of the report writing skills, a document analysis of ten final reports was done. Additionally, students were asked to complete a questionnaire to evaluate the importance of the individual interventions for their own report writing. To get a more detailed insight, six students were personally interviewed. Students were also asked to complete a Moodle questionnaire about their satisfaction with all virtual laboratories, and lastly, with our new Kjeldahl Labster lab (virtual lab), a small experimental study was performed.

Results of our investigations showed that the introduced interventions clearly improved the overall quality of laboratory reports. Consequently, the time needed by the teaching assistants to correct the reports was considerably reduced. The virtual laboratories were generally well accepted by the students and most of them are confident that they could transfer what they have learned from the virtual to the real space. A majority of the students think that virtual labs should be used more at ETH.

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Experiences with a classroom response system: Any more questions?!

A classroom response system was used in a medium-sized undergraduate lecture and provides advantages for formative assessment and interactive pedagogy.

Lecturers who want to encourage their class to actively participate during lectures can be disheartened. Particularly in larger classes, it is common for only a few students to answer questions and fewer take part in discussions around complex problems, which makes interactive pedagogy challenging. Lately, electronic devices, mostly hand-held remote controls (clickers) and more recently software-based classroom response systems (CRS) controlled via mobile phones, tablets, or notebooks, were employed and prompted a range of new introduction styles.

In this contribution, I present a framework for CRS implementation, how I integrated CRS in my undergraduate course in quantitative element analysis and address a number of encountered challenges. This is accompanied with an up to-date overview of software-based clicker systems, their features and comparison to the ETH Zürich EduApp. I discuss several examples with occasionally unexpected results for questions addressing potential misconceptions. An original and refined approach to collect additional feedback, exit tickets, demonstrates additional uses.

Although CRS are fairly easy to manage on a technical level, my experience reveals several and in the literature often not sufficiently addressed challenges. This includes formulating questions and handling results, which turned out to be quite complicated. For example, the transition from the commonly open-ended questions directly asked to the multiple-choice format routinely employed for CRS requires the concrete formulation of distractors (incorrect answers), which should also reflect held misconceptions of students.

Nonetheless, if CRS are appropriately applied they can enrich the lecture component of a course substantially with opportunities for formative assessments. CRS work like interfaces between lecturers and students, capable of handling much more response than direct verbal interaction and a greater variety of information can be transmitted than the show of hands. This may inform both lecturers and students about deficits. Defining specific aims, answering guiding questions and, accordingly, selecting an appropriate system are helpful steps to develop an implementation strategy.

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Flipping large university courses: How do student learning gains improve compared to lectures?

We have split a student cohort into two parallel settings, a flipped learning group and a lecture group. Comparing the performance results of both groups we can draw conclusions on immediate and medium-term learning effects.

Introduction

In the past, all ETH introductory physics lectures have been reformed and supplemented by active learning elements such as Peer Instruction [1]. A different approach consists of breaking up large lectures into smaller classes and shifting to highly interactive flipped learning settings. Studio Physics and SCALE-UP are well-documented implementations of this approach [2]. Running multiple parallel classes, however, implies substantial investment efforts (rooms, faculty) [3] and it is advisable to gain insights on expected learning improvements before deciding on either reformed lectures or small interactive class settings. A comparative study of student achievements between these two different settings is needed in order to guide pedagogical decisions going forward. For this reason, we have conducted a pilot study within a physics lecture class of 370 students.

Teaching concept

In a one-year undergraduate physics course, we divided the student cohort into two parallel teaching settings. During one semester, we offered a highly interactive flipped SCALE-UP environment to one group of 52 students and a reformed lecture to the

1) S.V. Chasteen, et al. (2011) J. College Sci. Teach 40.4 24-30
http://www.cwsei.ubc.ca/SEI_research/files/Physics/Chasteen_CourseTransformation_JCST2011.pdf

remaining 318 students. In the following semester, all students were taught in the same lecture setting without a SCALE-UP alternative. Within the 14-week parallel teaching period, we compared students' performance in both settings and could draw conclusions on immediate differences. Eight months after the SCALE-UP intervention, all students had to sit the same high-stakes final exam, which consisted of topics throughout the entire year, including topics from the previous intervention. We related the final exam results to the former performance results and gained insights on medium-term effects based on the two teaching settings. In addition, we analysed student feedback that included data related to class attendance, out-of-class preparation, level of intellectual challenge, and other items.

Analysis of student learning

- During the intervention period, students from the flipped SCALE-UP group outperformed students from the lecture setting. This performance gain, however, was substantially reduced when evaluated over the medium-term scale.
- For those students who participated in the 14-week flipped SCALE-UP group, we could not identify any transfer or modification of learning behaviour that would induce better performance outside of a dedicated flipped learning setting.
- Compared to the lecture students, students from the flipped SCALE-UP group did not invest more overall study time, even though they had to come prepared to class.
- The SCALE-UP students manifested an increased level of self-confidence in their own learning achievements.

Lessons learnt

- A single active learning intervention of one semester (14 weeks) is too short to sustain substantial performance gains.
- Even though students enjoyed the flipped class very much, their performance gains were much lower than those reported from the (mainly U.S.) literature.
- Curricular constraints such as contact hours and assessment conditions should be considered and adapted when shifting to a flipped class setting.

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2) R.J. Beichner (2014) New Directions for Teaching and Learning 137 9-16, https://doi.org/10.1002/tl.20081
3) E. Brewe et al. (2018) Phys. Rev. Phys. Educ. Res. 14 010109, https://doi.org/10.1103/PhysRevPhysEducRes.14.010109

Individualize learning through gamification and real-time dashboards

Lecturers can track the development of a course in real-time, while students have access to their progress with an individualized dashboard. The bonus system honours student activity by providing additional services and material.

Over the past 10 years, we have created engaging self-learning materials and a motivating didactical model to teach our first semester natural science students in computer science, which opens the possibility to discover important basic digital literacy competences on a scientific level. The aim of this project is to investigate how we can provide our learning materials and services for different student groups (e.g. novices, advanced, repeaters, etc.) on the basis of data from learning analytics. In order to achieve this goal, we have planned three complementary activities: Firstly, a gamification concept in the form of a bonus system is to be implemented for our courses. The idea is, that active learners are provided with attractive materials and services (e.g. repetition questions, mock exams, possibility for a preliminary grade, personal feedback on current performance, etc.) depending on their learning activity. In a second step, a student learning dashboard will be developed which is based on data from their learning analytics. It allows the visualization of the individual learning progress in small steps, so that even short activities lead to visible progress and put them into the context of the courses' learning goals. Thirdly, another dashboard helps the lecturers to monitor learning progress of large distributed cohorts in real-time. As a basis for the above-mentioned developments, a framework for learning analytics has to be created, which allows the collection and aggregation of student data from different data sources. This new structure could be of broad interest for many lecturers and learning professionals at ETH.

Success factors
Interesting and motivating high-quality self-learning units and an appropriate, effective didactic concept awarded with the KITE award 2018, already exist. They are proven and tested in practice in large scale first semester classes. The corresponding exam questions are reliable and valid. Evaluation instruments and the baseline of the key indicators are well known (long-term measurement). We are able detecting changes and responding appropriately if necessary. The project team has in-depth knowledge in learning analytics, data mining, data science, software development, teaching at large scale and project management. Together with the project partners, we are able to implement the project at a highly professional level. This project is broadly supported by lecturers and learning professionals from different departments.

Innovative elements
- *Real-time learning analytics:* Use of aggregated student data to develop and optimize learning materials in big distributed learning systems. Real-time analytics allows immediate feedback and interventions if necessary.
- *Implementation of a bonus system at large scale in first semester computer science-service courses:* This increases self-responsibility in the transition from high school to university. The bonus system should also help us to keep the dropout rate at a low level.
- *Pursue a gamification concept in three undergraduate courses:* reward active learners with additional learning materials and services as soon as they reach certain levels.

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Holucator – Lichens Edition: Targeting small organisms with the HoloLens

Immerse yourself in the microcosm of lichens using the HoloLens and learn how to differentiate different species using fascinating structures, just like environmental science students do on excursion.

On their biodiversity excursions students of environmental science map the distribution of a set of species belonging to an organism group. They prepare with an online tutorial consisting of an identification key, video material and a final test. In the field, however, the initial classification of certain groups of organisms is still difficult because size, appearance and detailed characteristics can differ from the visual material in the tutorials. Thus experts normally have to provide initial assistance.

In the case of lichens with their very stable location on trees, however, the Hololens can take over this function. Our Holucator app recognizes individual trees by their bark structure and highlights lichen colonies whose position has been entered previously in teaching-mode. Users can then interactively select species names in a multiple choice question, tag colonies of the same species or call up detailed information about the lichen species in focus, such as sketches of of charateristic structures. The Hololens-Architecture even allows to use conventional lenses at the same time. A total of 12 trees with 8 different lichen species are available at the Bürkliplatz site, so that several students can practice simultaneously and then begin with the actual species mapping.

The Holucator App was first used in March 2018 by a total of 40 students. The fascination with the new medium was clearly at the forefront of the students' feedback and the actual knowledge gained was not recorded. Nevertheless, we were able to establish that the time the students spent individually observing the lichens was clearly longer compared with the expert-instruction-scenario.

The Holucator (Lichen-Edition) App is the first outdoor application of the HoloLens at the ETH. It can be adapted for other similar applications, provided that the objects to be examined have a permanent location and a sufficient amount of fixed objects nearby to allow the HoloLens to orient itself in space.

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Innovation in precision agriculture: Facing the challenges of digitalization in agriculture

This is a new course to encourage the entrepreneurial mindset of the students around the topic of Smart Farming and connect them with different options available to further develop their own ideas.

Digitalization is disrupting the food system on a global scale: from the way we grow our crops, to the business models of the AgroFood industry. In this environment characterized by uncertainty and constant technological change, a new generation of professionals is needed to explore the new challenges and opportunities that continuously redefine the sector.

Despite the importance of entrepreneurship in agriculture, students of agronomy from the ETH in general do not engage in venture creation opportunities offered by the ETH or other institutions. This is highly relevant, as an entrepreneurial mindset in the students of agronomy is not only important to develop their own ventures, but also key to support farmers and companies of the AgroFood sector as they face the challenges of digitalization.

In an effort to revert this situation, the new course "Innovation in Precision Agriculture" was created. Organized by the ETH Studio AgroFood (WFSC), the course is designed to encourage the entrepreneurial mindset of the students and serve as a bridge to other courses already offered at the ETH on the topic of entrepreneurship. In particular, it aims to reach beyond the technological aspects of digitalization in agriculture, as creation, delivery, and capture of value become key aspects in the development of new venture opportunities. At the same time, the course aims to connect the students with different options available to further develop their own ideas within or outside the ETH. The course counts with the support of the chair of Entrepreneurship from ETH (MTEC), Student Project House (SPH) and guests lecturers from Agroscope and the private startup sector.

The first version of the 10-week pilot course will be offered to 16 BSC and MSc students of Agronomy. Focus will be given to the pre-launch and opportunity recognition stages of the entrepreneurial cycle, framed within the topic of Smart Farming. Students will be supported throughout the course by experts on technological aspects, as well as entrepreneurship, in the exploration and development of their own ideas until a concept prototype. Future versions of the course are expected to open gradually to students from Food and Computer Sciences in order to maximize the opportunities of collaboration and generation of ideas in a multidisciplinary environment.

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Innovation Leadership seminar

We use participant-centered tools that encourage students' reflection, their personal development and help them discover their approach to leadership. The course offers opportunities to learn in a real corporate environment though trial-and-error learning.

Introduction
The Innovation Leadership seminar aims at developing students' managerial and leadership skills by promoting their critical thinking processes. Additionally, it fosters the development of more traditional project management and innovation management expertise. In the course setting, the students work on a real-life project in collaboration with a leading company in the building industry.

Facts about the course:
- Kick-started by Innovedum fund for innovation in education
- Held since 2015 as a core course of the Master in Integrated Building Systems (MBS) and elective for D-MTEC MAS/Master students
- 6 ECTS = 180 hours per student
- 20-30 students with backgrounds in engineering, architecture and management
- Students take leadership in working for a corporate client on real innovation cases
- Partner companies are sector leaders and provide feedback from top management

Teaching concept

Our innovative teaching techniques focus on three areas of development: Innovation, leadership and project management.

Project Management:
Students learn to self-manage their project while being supported by numerous project management techniques, coaching exercises, and individual feedback through learning diaries. An additional focus is given to design thinking methods and prototyping tools.

Innovation:
Students learn about specific topics related to current innovation in the building sector in Switzerland. They learn to understand technology changes with an ecosystems view and think about the impact of new technologies in the building industry company (e.g. the commercialization of Building Information Modelling, BIM).

Leadership:
Students conduct a project with diverse stakeholders requiring them to take managerial, technical, personal responsibility for the real-life company case. This high pressure environment leads to an intense self-reflection journey, team experience and fertilizes their pro-active behavior towards the client. On the personal level, students have to identify and achieve their very own authentic learning goals. Teaching tools involve the learning diary and self-assessment tools of individual abilities and traits, which helps their reflective journey and teaches them self-directedness. On the team level, students are teamed up to deliver a real-life project to the company. The teams are diverse and the students' work focuses on cooperativeness and how to be effective team members. Teaching tools involve peer-to-peer feedback, coaching and open space workshops. On the company level, students learn how to deal with different stakeholders and how to create impactful and sustainable solutions for their client.

Course Design:

- Real project: non-trivial real project with a demanding client, e.g. develop a market entry strategy for a new technology, evaluate and improve the roll-out of an innovation management process
- Leadership development: project with diverse stakeholders requires talking different languages - managerial, technical, personal. Real responsibility creates high

pressure leading to intensive team experience. Personality profiling, learning diaries and coaching fertilizes proactive behavior
- Repertoire: students learn and apply methods in project management, innovation, strategy and design thinking along the project with bi-weekly workshops – always related to real projects
- Topical learning: specific topics related to innovation in the building sector flow from real case and each team's research

Analysis of student learning

This course is challenging for students, because it promotes their self-directedness and their critical thinking abilities. Students need to define their very own learning goals and are assessed and graded on whether they have progressed towards achieving them. This approach teaches students to:
- Reflect and explore possible personal goals and discover new ideas
- Learn to work in an unknown direction with no certain outcome
- Explore how a project with internal and external stakeholders works when people have conflicting interests, that might also vary according to the different time perspectives that are taken into account
- Use design thinking and solution-oriented coaching techniques

Lessons learnt

Students passionately develop new and innovative projects for the partner company. They gain hands-on experience with a real project and deep-dive into rich reflections about their personal opportunities both on leadership and innovation in this process. Students enjoy the innovative teaching techniques. Often times, they need to learn to adjust on setting their own learning goals and getting into a "critical thinking mindset".

Transferability and sustainability:

The question of whether what students learn in the course will be remembered and used after the course, is a central question for the faculty involved. In order to evaluate to what extent "what students learn in the course does not stay only in the course" we are currently in conversations with the MBS program coordinator planning an evaluation that should take place as soon as a higher number of students from the program will graduate.

On the topic of sustainability, we have had, so far, two different takes. First, whether the course could keep running without the support from Innovedum. Second, whether we can promote a view of innovation that is not separated from sustainability. On the first point, we have redesigned and redistributed the roles of the different course contributors in such a way that the course can now run also when the funds from innovedum are over. On the second point, we promote student's sustainability thinking by asking them to critically evaluate their creative ideas under the light of the different actors involved, as winners and losers, in the past, today and in the future.

Challenges:
Is such a "teaching intense" course scalable from 30 to 120 students?
Is such a course suitable for all student's personalities, professor's personalities and type of programs?

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IÖ-APP, real estate application

Retrieve, combine and assess various real estate parameters in order to arrive at indicators for appraising the value and potential of property.

Introduction
The IÖ app aims foremost to provide students with a more innovative, intuitive tool than a pocket calculator, or Excel; one that suits the subjective nature of real estate potential analysis. The mobile app also seeks to better accommodate the site-dictated nature of the architectural discipline. It would furnish students with a hands-on tool for appraising real estate parameters in real-world settings, visibly reinforcing for them the direct link between the built environment and its surrounding economic context.

Teaching concept
The concentration and elective subjects administered by our chair build on the compulsory undergraduate core subject, Building Process I+II. The lecture series focuses on the building process as a chronological sequence of design services and construction work. It covers the subject areas: building law and acquisition; building economics and sustainable strategies; participants and their services; and construction contractors and design professionals. In addition to discussing the fundamentals of the building process, its tendencies and terminology, projects of architectural and urban relevance are drawn on to explore the respective subject areas in greater depth. Each topic is viewed from the standpoint of form, area(s) of responsibility/competency, and communication. Active participation as well as interdisciplinary and process-orientated thinking is expected of students. In the graduate-level concentration subject, Building

Process: Economics, students have the opportunity to examine in greater depth the thematic focal area, Building Economics and Sustainable Strategies. The standard weekly lectures and presentations are accompanied by project-based instruction. In the form of real-life scenario exercises, students learn to independently decipher what is and is not relevant to a project, and then practically apply the competencies presented and outlined in lectures. The assignments require a large degree of interdisciplinary competency in the areas of urban and architectural design practice, building and tax law, mathematics, sociology, and economics.

Analysis of student learning

The students really like the application format of the new tool and are able to use it independently after a short introduction during the semester's first lecture. Their first approach usually consists of analysing the plot of land where they live, or -by using the "locate me" function- the plot where the ETH-building the lecture is taking place is located. By applying the application on various plots, they seem to gain an understanding of the city's underlying economic forces and their manifestations in the built environment.

Lessons learnt

Students nowadays are used to smartphone applications and augmented reality functionality, making it possible to combine data with the environment and interacting with it. The entry barrier for using the application was therefore very low, once the underlying economic principles were taught and understood. STEM-learning-wise the application represents almost a model case-study for combining data, skills and experience from various fields in one subject. Some of the data the application is using right now is static and therefore outdated within a very small timeframe. Our goal for the future of this app is to directly receive this live- data via an API.

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fpre- Fahrländer Partner Raumentwicklung / b+p baurealisation / ARE- Amt für Raumentwicklung des Kantons Zürich / AfS- Amt für Städtebau der Stadt Zürich / liip ag- Technische Umsetzung, UX-Design, User stories

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Laboratory practice energy efficient production

The students understand the challenges of energy efficient production by using a research oriented learning approach.

Introduction

About 30 % of the electrical power in Switzerland and Europe is used by industry. Therefore, there are pan-European ambitions to reduce the consumption of electric energy in industry. Due to the high precision requirements in the manufacturing sector a large fraction of the energy consumption is required for the thermal stabilization of the equipment such as machine tools or metrological instruments and machines. Particularly, the heat losses generated by the components have to be removed out of the structure by investing power into the cooling system. In contrast to other industry sectors such as robotic, automotive and aircraft industry, in manufacturing systems small temperature changes can already result in critical dimensional errors. In the scope of the three lab courses the students have the unique opportunity to deal in detail with the on-going challenges of energy efficient production. The teaching concept is goal and method oriented to strengthen the critical thinking of the students. Thus, the first learning objective is to understand the problem of energy efficient production and the correlations within this field. The remaining learning objectives are method oriented and include how to analyse complex relations within engineering tasks, how to model them and how to derive measures from engineering models and implement them in real machine tools.

[1] ISO 14655, 2018, Machine tools -- Environmental evaluation of machine tools -- Part 2: Methods for measuring energy supplied to machine tools and machine tool components. [2] Gontarz, A., Weiss, L., Wegener, K., Energy Consumption Measurement with a Multichannel Measurement System on a machine tool.

Teaching concept

The teaching approach which is used for these lab courses combines theoretical explanations and applied exercises at the forefront of research. The structure of the lab courses includes recent research findings in the field. The theoretical explanations support the students to get expertise on the topic of energy efficient production while the applied exercises improve their engineering and implementation skills. In the following sections the teaching structure of the three lab course is explained.

The Green Machine Tool: How Does Energy Efficient Production Work?

The course starts with a theoretical discussion and analysis of the life cycle of machine tools. It continues with an applied part where the students get to measure the energy consumption of a machine tool during the use-phase. The students perform a power measurement according to ISO 14955-2 [1] on a five-axis machine tool. The power measurement system is especially designed for this lab course as a further development of the already existing measurement system of IWF, developed by Gontarz et al. [2] and applied to the Mori Seiki NMV 5000 DCG by Züst et al. [3]. During the measurement the energy consumptions of several machine tool components are measured at different operating states. The obtained data is used in order to calculate the energy consumption of each component in relation to the total power. In the last part of the course, the connection between energetic losses and the accuracy of the manufactured product is explained, providing the connection with the next course unit.

The Deformed Machine Tool: How Do Heat Losses Cause Manufacturing Errors?

This course analyses the thermal chain of causes, which describes the physical fundamentals leading to thermal deformations of the machine tool. Due to the long time constants of the thermal behaviour of machine tools, the experimental investigation is performed on a test bench, which reacts much faster. The test bench, especially designed for this course, consists of an aluminium structure to ensure measurable thermal displacements with small time constants. An online visualization of the measured temperatures and temperatures displacements is provided so that the students can immediately evaluate the changes due to different configurations of the heat sources. Allowing the students to interact with the test bench provides an understanding of the relations between the configuration of the heat sources, the temperature field and the TCP displacements. The course continues with developing and validating a physical FE model of the test bench. After the validation of the model, the students can try different

[3] Züst, S., Blaser, P., Mayr, J., Knapp, W., Wegener, K., 2017, Thermo-energetic issues in 5-axis machine tools, in MTTRF 2017 Annual Meeting. [4] ISO 230, 2007, Test code for machine tools -- Part 3: Determination of thermal effects, Geneva, Switzerland.

load case scenarios faster than in the measurement setup of the test bench. This demonstrates the benefits of physical modelling to the students, as different design modifications or load cases can be evaluated in a more efficient way than performing measurements directly with the physical prototype. The simulation and measurements on the test bench are furthermore extrapolated to understand the thermal behaviour of machine tools. In the last part of the course, the students propose different alternatives on how to improve the thermal behaviour of machine tools. This provides an outlook to the next course unit where the online compensation of thermal errors is explained in detail.

The Machine Tool 4.0: How to make precision manufacturing energy efficient?
This course focuses on the online compensation of thermally induced position and orientation errors of a rotary axis. Two different approaches are followed, namely physical and phenomenological compensation models, both introduced by Gebhardt et al. in [5] and [6] respectively. First the students create their own thermo-balance compensation model by establishing the heat transfer equation for each considered body of the machine tool. The resulting TCP displacements are then calculated using simplified geometrical information about the bodies. Using experimental data of the machine, the students test the accuracy of the created thermo-balance model. In the next part of the course another compensation approach is presented, phenomenological models. The students are provided with over 90 hours of measurement data, i.e. thermal errors and temperatures, from the machine tool Mori Seiki NMV 5000 DCG. The students feed measurement data over 60 hours in a phenomenological compensation model for each considered error type to obtain the model parameters and use the remaining 30 hours to test the resulting models. Afterwards, the students use the Fanuc Control (Interface FOCAS 2) of the machine tool and a measurement PC as cyber physical system to implement their compensation model in the machine tool. The course also outlines the potential of increasing the accuracy of the compensation models when large volume of data is available, which is facilitated by the new trend towards Industry 4.0.

Analysis of student learning

The developed lab courses provide the students a research oriented learning approach, in which the students apply new and already acquired theoretical skills to current research questions. Thus, the course structure is developed in a strongly interactive manner which enables a direct observation of the stated learning objectives. The different

[5] Gebhardt, M., Mayr, J., Furrer, N., Widmer, T., Weikert, S., Knapp, W., 2014, High precision grey-box model for compensation of thermal errors on five-axis machines, CIRP Annals - Manufacturing Technology, 63/1:509–512. [6] Gebhardt, M., 2014, Thermal behaviour and compensation of rotary axes in 5-axis machine tools.

exercises including the measurement results are directly presented and discussed by the students during the lab course, so that the supervisor can directly assess their learning progress. This enables a high- level interaction between the bachelor students and the supervisor and enforces the learning success of the students. Furthermore, the extensive practical application of the elaborated solutions supports the supervisor to evaluate the fulfilment of the learning objectives. Finally, the students demonstrate their learning progress by including their findings into a report template.

Lessons learnt

The first runs of the lab courses showed, that the strong interaction between theoretical and practical elements in the context of current research questions results in a high motivation of the students. Furthermore, the students appreciate the connection between technical and social challenges of the given exercises. The three lab courses indicate that this teaching concept is an excellent opportunity to integrate current research findings and the required research methods into teaching. For the students this lab course provides the opportunity to familiarize with machine tools, which allows them to access this knowledge in future courses related to production and machine tools. This lab course is sustainable in two different ways. First, the lab courses create awareness for the scientific and social challenge of energy efficient high precision manufacturing. Second, the lab course is sustainable for the improvement of their academic skills because they familiarize with methods by applying them to a specific problem. The concept of these lab courses can be easily transferred to other fields of research as an innovative concept for research oriented learning and teaching of application competence.

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Make it tangible: Laser cutter models in first-year mechanical engineering education

Interacting with portable and operable physical models of commonly used machine components supports first-year students in understanding underlying working principles and mathematical relations.

The course Maschinenelemente is part of the first-year education in mechanical engineering and is currently attended by more than 500 students. The didactic concept aims at imparting profound knowledge of how commonly used machine components are designed and how they work in detail within a technical system. In this context, a basic challenge lies in teaching the more complex components that are usually characterized by a high number of interacting parts and interfering movements.

In recent years, we tested several approaches to meet this challenge. We found that portable and operable physical models are most helpful to enable students to establish a deeper understanding of the subject matter. Such models can be already presented during the lecture, but it is even more important to give the students the opportunity to make their own experiences by operating and modifying the models by themselves and closely analysing the interaction of single parts.

The Innovedum project "Make It Tangible" introduces an educational framework utilizing portable and operable physical models of commonly used machine components in order to facilitate the students' process of understanding. In the first part of the ongoing project, we developed blueprints and assembly instructions for Laser Cutter Models. Laser Cutter Models are models made of wood or acrylic glass that represent single mechanical mechanisms in a simplified way. Guided by the instructions, our first-year students can now easily produce their own models and analyse them together with their fellow students (peer-learning). They also can take the models home and explain them to friends and family. For learning assessment, we developed online quizzes provided via the ETH Moodle platform. These quizzes include questions that ensure the students have correctly understood the theory behind the models and test whether they are able to transfer their knowledge to solve similar problems with changed requirements.

By implementation of this Innovedum project, we initiated a more intensive learning experience that is especially characterized by a closer linkage of theory and practice and a more active role of the students. The Laser Cutter Models substantially supported our students in understanding underlying working principles and mathematical relations. We experienced that the students have quickly acquired a deep level of specific knowledge and furthermore, that they have trained their technical communication skills at a very early stage of their studies.

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Parametric phenomena workshop

We present a flipped classroom approach to teaching parametric phenomena. Through simulated experiments, reading, and guided analytical exercises, the students build a deep understanding of complex nonlinear phenomena that appear accross many fields of physics and engineering. In a poster exhibition, each participant showcases one particular manifestation of the very general physical model.

The overall goal of the course was "Students can understand parametric phenomena both theoretically and experimentally". With this goal in mind, we wanted to let the students experience a "hands-on" taste of the methods used in the analysis of various contemporary physical systems, where parametric phenomena play an important role. We faced the following dilemmas: in order to show the ubiquitous nature of the phenomena, we would have to teach the foundations of a wide variety of physical platforms, whereas the course's focus is on the universal analytical and numerical methods used in the analysis of such systems. Furthermore, many of these methods are covered in well-written books and we did not think that the process of copying information from a blackboard would provide the deep learning experience that we were looking for.

Our solution to these dilemmas involved the following course structure: (i) to address the ubiquitous nature of parametric phenomena, each student was given a physical system to analyse during the semester. The student could then apply the universal mathematical and numerical methods taught in the course to his/her system, and share the specific manifestation of his predictions with the rest of the class during the course hours (when working in pairs) and in the final assessment (where each student presented his/her project in a poster session); (ii) the delivery of the course material involved gradual pointed reading of selected chapters in several books and guided exercises during the course hours that emphasized the applicability of mathematical methods. We have provided the infrastructure with which to apply the analytical and numerical methods discussed in the book chapters during the guided course hours. Conceptual topics and challenges were discussed weekly during intermediate consolidation sessions.

We believe that this approach has given our student a wide set of tools that were "deep-learnt" through repetition and exercise. Such a method can be easily adopted by a wide variety of advanced middle-sized courses where the students have already learned some self-teaching skills.

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Wunderkammer / Cabinet of Curiosities: Perceive, Collect, Organise, Translate, Visualise

The Wunderkammer / Cabinet of Curiosities project is a web platform that provides an interactive research tool for landscape architecture and design-relevant tools to support the design process at the interface between teachers and students.

The design process comprises all of the following steps: research, analysis, programme, development and communication. Here the selection and evaluation of different information and what links and contextualises it as well as the translation of knowledge and individual experience through various design tools are important skills. The Wunderkammer/Cabinet of Curiosities platform supports the design process and helps with the presentation of these individual design steps.

1. Specific contextualised knowledge: The platform offers quick access to design-relevant landscape architectural knowledge for architecture students who choose landscape architecture as an elective subject. The style of navigation promotes independent elaboration on, and linking of, the content, which exposes students to different perspectives and allows them to explore terms and definitions in various contexts.

2. Gather knowledge and organise it: Students can use the platform either as part of a course at the Chair of Professor Vogt or independently. Users plan their research as project-specific 'collections' which they can organise according to various parameters

and thereby reveal new connections. Using prescribed layouts, the collected material can be structured, expanded with images and texts and used as a knowledge base for design.

3. How do we apply design tools? The platform encourages students to take a considered approach to design tools and their appropriate application. It also encourages them to think about which technical and design methods are appropriate by demonstrating their use in a variety of disciplines.

Success factors

The platform meets the varying demands of architecture students at different stages of their education and makes a quick and targeted access to landscape architecture possible. The project is a long-term investment: its coordination with the teaching and research activities of the Chair of Professor Günther Vogt guarantees that content will be continually expanded, kept plentiful and up-to-date. The platform is not only for teaching, but should also be useful beyond that to include individual projects, research, or questions from students, e.g. developing a design for another Chair, preparing for exams, for questions on landscape etc.

Innovative elements

The project creates for the first time a specific, design-relevant knowledge base on the themes, types, methods and tools of landscape architecture for architecture students. The potential of the online medium lies in intelligent linking and representation of knowledge, stimulating navigation through the content and the creation of an interface between digital and analogue, between teaching and independent learning.

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Lecture-coordinated project-based laboratory course

A project-based laboratory course was introduced to promote synergies by coordinating a chemistry lecture with a laboratory course and to strengthen the autonomy and critical thinking of the students.

We introduced a project-based laboratory course in the 4th semester of the material science curriculum of the Department of Materials. The course is held parallel to the lecture Chemistry IV such that the topics of the projects could be well adapted to the lecture contents.

Instead of detailed instruction for a synthesis or experiment, the students receive a short introduction into the topic along with a problem to be solved. Thus, they have to plan their experimental work largely autonomously while working in teams of four persons. There are two main objectives of the course: (1) Application, deepening and repetition of important aspects of the associated lecture. We expect that the learning process of the lecture contents is supported by practical work. (2) Promotion of critical thinking and of a systematic working in a laboratory. Particularly, we would like to facilitate the transition from classical laboratory courses to autonomous research (e.g. in Bachelor and Master theses).

We believe that project-based laboratory courses are a promising approach to promote autonomy of students. However, planning and running such courses can be difficult and requires much more experience than classical laboratory courses. In our opinion, a good laboratory course can be achieved with both classical instructions and a project-based approach. However, project-related courses seem to be more sensitive and error-prone and therefore need to be well thought out.

Acknowledgements
Because the laboratory course was conducted and modified in accordance with a part of the Chemistry IV lecture, we are extremely grateful to Prof. W. Caseri for the necessary adaptations of the lecture to the laboratory course and the very helpful and enthusiastic discussions of the projects. We would also like to thank the numerous assistants, who spared neither time nor effort to adapt the projects even better to the needs of our students. We are also grateful to the students who, with their great commitment and creativity, made the success of the project possible.

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Systemic Design Lab: Incubating systemic design skills by experiential didactics and nature-based creativity

Outdoor experiences, fabrication and transdisciplinarity empower students as change agents for sustainability, developing skills in critical systems thinking, bio-inspired creativity, circular design and service understanding.

In this new, integrated modular block course for interdisciplinary MSc and PhD students, established technical planning and engineering methods are combined with ecological design thinking, nature-inspired creativity and service understanding to better cope with the increasing complexity of current and future sustainability challenges.

Students are being empowered to proactively design processes, products and services from a systemic perspective, where ecological life cycle design is integrated with technical planning and engineering skillsets, in relation to socio-economic factors, user needs and spatial development. The Systemic Design Lab (SDL) initiative builds on established teaching in engineering, planning and design while introducing systemic design thinking and doing in an innovative format based on experiential didactics and outdoor creativity.

We use bio-inspired design or biomimicry, fabrication and prototyping with sustainable materials, and systems- or supply chain mapping of product/process/services to spur creativity, holistic thinking and critical reflection within a sustainability context.

Students learn to inhabit the "view from above" – zooming out of the direct problem focus to see the underlaying structure and identify leverage hubs with systemic impact – and zooming in again with the needed focus on details that matter most.

Explicitly, students acquire life cycle analysis, supply chain mapping and circular design skills, to both quantify and minimize the undesirable negative environmental footprint while increasing the regenerative, net-positive contribution of their design solutions. Fabrication and material science are taught by actually designing and prototyping while engaging in transdisciplinary partnerships for societal impact and real-world experience. Students gain a whole-systems understanding of the relation between products, processes, services, economies and lifestyles to up- and downstream flows of matter, energy and people mobility, within a spatial framing.

In the SDL course displayed here, students prototyped an educational fabrication kit – for building snow shoes – as a tool for schools and the public to teach sustainability. The educational snow shoe toolkit is optimized for circularity and environmental impacts, while displaying timely engineering skills like 3D printing and laminating with upcycled and renewable materials like bio-plastics and flax-Paulownia composites. The technical design details are inspired by nature's creativity and adhere to general systemic design principles. The public "Student Project House" at ETH Höngg provided the needed facilities for creative design thinking, fabrication, and nature access.

The prototyped toolkit now enters the transdisciplinary testing phase with schools before possibly spinning-off for its upscaled market implementation. Future SDL courses will employ and further improve this systemic design approach while focusing on varying fabrication and planning themes.

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UN-Habitat ETH-CASE Housing at the Centre workshops: From the new urban agenda to systematic approaches

In partnership with UN-Habitat, ETH-CASE organizes Housing at the Centre workshops for students to work on real housing challenges alongside national and UN-Habitat experts to support newly issued National Housing Plans.

The Idea: This Innovedum project offers innovative educational events to ETH students to work on actual housing challenges and ongoing housing sector reforms. The aim is to train a new generation of built environment professionals which, according to UN-Habitat officials, is needed to successfully implement the New Urban Agenda. Between 2018-2020, three housing studios are developed by ETH CASE and in partnership with UN-Habitat that bring together ETH students with housing experts of a partner country. During these one-week events, a recently elaborated national housing plan, which lays out the broad system of housing delivery and government interventions in a country is translated into more concrete strategies and design proposals. Students not only receive the unique opportunity to work on a real case application and see their ideas eventually manifest, but also get valuable insights into transnational policy making, current urban development challenges in the Global South, and transdisciplinary working environments. Results will be displayed in Zurich, the UN-Habitat headquarter in Nairobi, as well as the partner countries and additionally published through online and print documentations. The long-term aim is to fully integrate the ETH-UN-Habitat collaboration into the curriculum offer of ETH-CASE as well as other collaborating departments.

Current Status: In Spring 2018, a pilot workshop was organized to adjust to a modified implementation timeline. During this event, a small group of MAS in Housing students guided by ETH CASE staff and an UN-Habitat expert reflected on the specific housing challenges in Mozambique and developed project ideas based on incremental growth. The workshop has been published in the social media of UN-Habitat and results post-produced into an UN-Habitat presentation. The learning experience of students were captured in short video statements and used to create a promotional video for the Housing at the Centre initiative. For the academic year 2018-19 all activities are integrated into the curriculum which include a lecture series on housing issues of the Global South, a preparatory seminar more specific to the particularities of Mozambique and a seminar week visit to the partner country.

Next Steps: In Spring 2019, a large workshop is organized aiming at uniting different ETH departments and, eventually, different universities. In a combination of on-site and skype lectures, as well as interdisciplinary group work, students learn to think across disciplines and scales and develop reflective competences that enable to connect architectural decision-making to its broader effects (such as affordability, resilience, urban patterns,...).

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MOLEGRAM Explorer

Mixed Reality application for students to dive into the world of molecules. You become a water molecule and can take a holographic walk on a protein surface.

We present the MOLEGRAM Explorer which allows students to better understand the concept of the solvent-accessible molecular surface. In the Computer-Assisted Drug Design practical class, the participants use this application to examine and interact with a protein and learn the influence of different solvents on the protein structure. The application is designed for a 15 min. usage, including an introductory movie. 15-20 min. are required to familiarize oneself with the Hololense hardware. The MOLEGRAM Explorer enables collaborative learning by providing a real-time synchronized view of the hologram to all participants. A shared pointer allows the instructor to focus the participants' awareness on certain areas of the protein. The application also offers the "Explorer mode" allowing the students to apply the new concept in an individualized environment. Currently, the cumbersome handling of the Hololense hardware limits its practical use to small groups. For the best experience, a sufficiently large empty space is needed. Only then, the participants can fully submerge into the topic by physically circle and investigate the virtual hologram. As a prerequisite, a basic understanding of protein structures is required.

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Using applets in math courses

We used applets in math courses as a visual aid to animate aspects of mathematics where static drawings and oral explanations cannot ideally transport the main idea. We present some examples and discuss students' feedback.

Many students find it difficult to visualize geometric objects, such as graphs and curves. Moreover, most first year students lack familiarity with computer algebra systems (e.g. Matlab). To address these difficulties, in 2016-2018, we used interactive applets in several first year D-Math Analysis courses for various engineering departments. The applets were used during the lectures as dynamic visual demonstrations, and were linked to in the lecture notes for individual experimentation and learning. Moreover, some applets were used in interactive exercises and as a tailor-made computer algebra system that does not require prior knowledge from the students. Most of the applets were created using Geogebra. We will present some of these applets and show how they were used in the classroom and how they can be embedded into interactive lecture notes (such as E-Skript). We will also discuss the detailed feedback we've received from the students enrolled in the courses implementing the applets.

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Apps / Mobile
Learning

Audiovisual
Media

Authentic
Assessment

Competence-Oriented
Learning

Engaging with Simulation
and Gaming

Entrepreneurship and
Transdisciplinarity

Flipped
Classroom

Global
Citizenship

Interactive Learning
(Collaboration)

Non-Disciplinary
Competences

Peer
Review

Research-Oriented
Learning

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