

2023

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Recommended Citation

Rattleff, P., & Sass, D. S. (2023). Teach As You Preach: Teacher Training For STEM-Educators At DTU. European Society for Engineering Education (SEFI). DOI: 10.21427/6BZA-7C58

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Teach as you Preach: Teacher Training for STEM Educators at DTU

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Conference Key Areas: *Innovative Teaching and Learning Methods & Curriculum Development*

Keywords: *Constructive Alignment, Teacher Training, Active Learning, STEM in Higher Education, Sustainable Learning Processes*

ABSTRACT

At technical universities today, we are training students for jobs that do not yet exist, to use technologies that have not been invented, to solve problems, we do not even know are problems yet. To succeed, we must create sustainable learning processes allowing our students to construct proper conceptual understanding and be able to retrieve, transfer, and apply knowledge, skills, and competences in new complex settings.

To facilitate such learning processes, higher education institutions must train excellent teachers. This paper presents the framework for STEM teacher training at DTU – Technical University of Denmark. A framework that claims exactly to train excellent teachers by practicing what we preach: Employing a student-centred approach focusing on student motivation with active learning and constructive alignment to ensure conceptual understanding.

Rather than presenting long theoretical lectures to the participants of our teacher training programme, we – from day one – ask them to engage in a range of carefully planned activities designed to scaffold the construction of sustainable knowledge, skills, and competences that can be activated in unknown future contexts. Exactly as we wish for them to do with their own students.

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1 INTRODUCTION: THE TEACHER TRAINING PROGRAMME AT DTU

"For many university professors, teaching is like being handed the keys to a car without being taught how to drive. [...] The unstated assumption is that if you have a degree in a subject, you must know how to teach it at the college level."²

However, at DTU – Technical University of Denmark, we strive to educate not only the best graduates, but also excellent teachers.

The teacher training programme at DTU is called UDTU. UDTU equals approximately 250 working hours and can be completed within a year. Each year, approximately 60 participants take part in the teacher training-programme. In this paper, we refer to DTU-students taking part in a bachelor, a masters or a Ph.D.-programme as *students*. We refer to the assistant professors, post. docs and senior researchers taking part in the teacher training programme as *participants*.

UDTU has two foci, namely:

- 1) The design of a DTU course and
- 2) The development as a university teacher.

We, the facilitators of the UDTU programme, offer *just-in-time teaching* and supervision, and throughout UDTU, participants carry out a number of teaching and learning activities. The activities are tasks done individually, in pairs, triads, and in groups of four to six peers.

During the first semester of UDTU, the participants take part in several facilitated sessions with a duration of one to three days. These sessions focus on teaching methods, didactical design, feedback, assessment, constructive alignment, and motivation. During the second semester of UDTU, the participants try out and evaluate the DTU course they have designed during the first UDTU-semester.

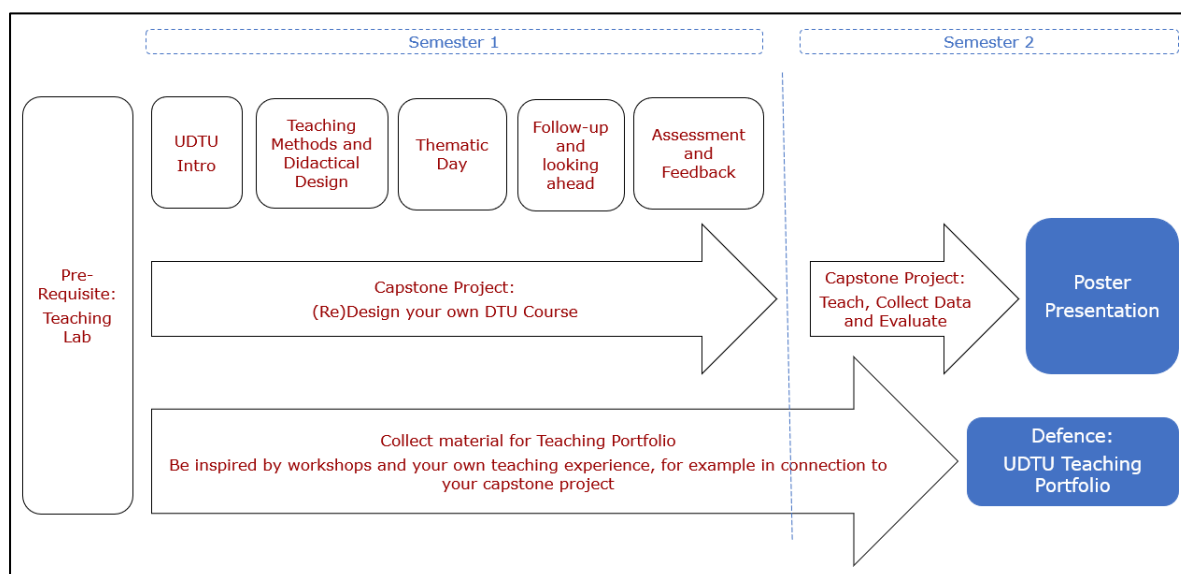


Fig. 1. UDTU Roadmap

² Felder, Richard M. and Brent, Rebecca. *Teaching and Learning STEM A Practical Guide*. San Francisco: Jossey-Bass, 2016, XV, I.

The overall learning objectives of the UDTU programme can be seen in Figure 2.

- Plan, teach, develop, and evaluate student-centred and learning outcome-based teaching at DTU.
- Design a teaching sequence, preferably an entire DTU course, using innovative teaching methods and didactical design to promote student motivation and scaffold student learning and conceptual understanding.
- Design a DTU course using constructive alignment and formative feedback to support students as self-regulated learners.
- Reflect on and continue your development on becoming an excellent DTU Teacher.
- Contribute to the development of courses and educational programmes in higher education.

Fig. 2. UDTU Learning Objectives

The design of the UDTU programme is inspired and informed by *constructive alignment* (developed by John Biggs³), the *Theory of Didactical Situations in Mathematics* (developed by Guy Brousseau⁴), and the *model of student motivation and persistence* (developed by Vincent Tinto⁵).

In this paper, we describe the overall teaching philosophy and the didactical design of the programme with a focus on constructive alignment, other aspects of the UDTU programme will be covered elsewhere. First, we outline the overarching teaching philosophy of the DTU Learning Lab. Then we introduce constructive alignment along with examples of how this is practiced in the UDTU programme.

2 TEACHING PHILOSOPHY AND DIDACTICAL CONTRACT

The overarching teaching philosophy of the DTU Learning Lab is *Granny's Law* as formulated by Danish researcher, Steen Larsen. Granny's Law stipulates "the person, who works, learns. Period."⁶ Thus, for the UDTU participants to learn, they must do the work – by actively engaging in teaching and learning activities.

At the outset of the UDTU programme, we establish a strong *didactical contract* with our participants. During the facilitated sessions, we have just-in-time teaching, but no regurgitation of literature read as preparation. The didactical contract is developed by French mathematician Guy Brousseau and clarifies the responsibilities of the facilitators and the participants⁷. The didactical contract states that learners must learn, and teachers must create space and opportunity for learning to take place⁸.

The UDTU participants must design a DTU course with carefully thought-out, high-level learning objectives. They design worthwhile and productive teaching and learning activities guiding the students towards their learning outcomes and lastly, the courses must have suitable formative feedback and summative assessment of student learning and learning outcomes. Thus, the UDTU programme itself is designed exactly like that - according to the three pillars of good teaching and learning at DTU (figure 3 below).

³ Biggs, John and Tang, Catherine. *Teaching for Quality Learning at University*. New York: Open University Press, 2011.

⁴ Brousseau, Guy. *Theory of Didactical Situations in Mathematics*. Dordrecht Boston: Kluwer Academic Publishers, 1997.

⁵ Tinto, Vincent. "Through the Eyes of Students." *Journal of college Student Retention: Research, Theory & Practice* 19, no 3 (2017): 254-269.

⁶ Larsen, Steen. *Den ultimative formel for effektive læreprocesser*. Hellerup: Steen Larsen, 1998, 37 (own translation).

⁷ Brousseau, Guy. *Theory of Didactical Situations in Mathematics*. Dordrecht Boston: Kluwer Academic Publishers, 1997, 227ff.

⁸ Skott, Jeppe and Jess, Kristine and Hansen, Hans Christian. *Matematik for lærerstuderende*. Frederiksberg: Samfundslitteratur, 2008, 421.

3 BASIC PRINCIPLE: CONSTRUCTIVE ALIGNMENT

Although constructive alignment as an educational concept has existed since 1999, it is our experience that it has not consistently been implemented in higher education. For this reason, UDTU has a strong focus on both the theoretical model and practical demonstration of constructive alignment, essentially, we teach as we preach.

Constructive alignment is the notion of American learning theorist, John Biggs, that the learning objectives, the teaching and learning activities, and the assessment should be *constructively aligned* to support one another⁹.

In other words, each and every educational element should have clearly defined learning objectives stipulating what the students should be able to do after the completion of e.g., a course, a lecture, an assignment or a project in terms of knowledge, skills, and competences. At DTU, we use Bloom's revised taxonomy of educational objectives when formulating learning objectives¹⁰ (see figure 4 below).

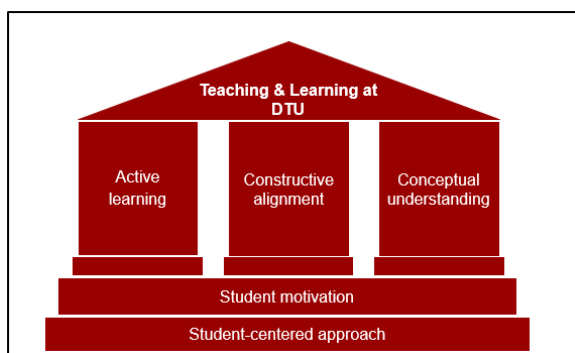


Fig. 3. Pillars of good teaching and learning at DTU

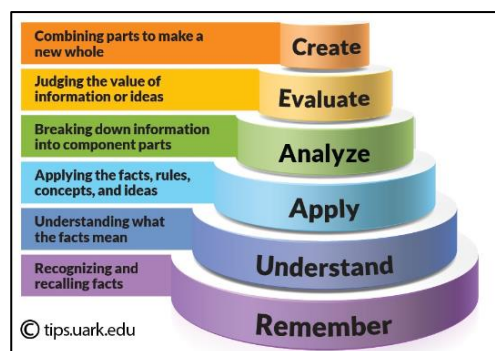


Fig. 4. Bloom's revised taxonomy¹¹

To guide and support students to achieve the learning objectives, teaching and learning activities should be carefully designed. These activities could include teaching, preferably as just-in-time teaching, tasks, and assignments for students to work with individually and in groups, projects, fieldwork, lab exercises, and experiments. While taking part in the carefully designed teaching and learning activities, the students will acquire the knowledge, skills, and competences stated in the learning objectives. Following this, the exam should evaluate the extent to which the students have indeed met the learning objectives.

Students will learn whatever it takes to pass the exam. This is known as the *backwash effect*, which is the observation that the exam of a course washes back and guides the student behaviour and learning outcome¹². If alignment and overlap between the assessment and the learning objectives is not present, students will merely learn what it takes to pass the exams. If we want our students to construct a

⁹ Biggs and Tang *Teaching for Quality Learning*.

¹⁰ Krathwohl, David. R. "A Revision of Bloom's Taxonomy: An Overview." *Theory Into Practice* 41, no. 4 (2002): 212-218.

¹¹ Shabatura, Jessica. "Using Bloom's Taxonomy to Write Effective Learning Outcomes." University of Arkansas Tips. University of Arkansas, July 26 2022. <https://tips.uark.edu/using-blooms-taxonomy/>

¹² Andersen, Hanne Leth and Tofteskov, Jens. *Eksamen og eksamensformer. Betydning og bedømmelse*. Frederiksberg: Samfundslitteratur, 2016, 19.

proper conceptual understanding and formulate this as an overall learning objective for the course, it should not be possible to pass the exam without a proper conceptual understanding.

3.1 Constructive Alignment in the UDTU programme

As mentioned, the UDTU programme has two foci: the participants' development as a teacher and their design of a DTU course. Throughout their UDTU journey, the participants make two products: a UDTU Teaching Portfolio and a Capstone Project Poster. The Teaching Portfolio is the vehicle of the first focus, and the Capstone Project is the vehicle for the second focus.

The overall assessment of UDTU has been carefully thought out to assess the extent to which the participants have achieved the learning objectives of the programme. Furthermore, and perhaps more importantly, the intention is to activate a measure of sustainability in the sense that the products continue to live after completion of the UDTU programme, outside of the UDTU ecosystem in contributing to the development of the teaching practice at DTU more broadly and reach into the future of both the individual teacher, and STEM higher education as a field of practice.

3.2 Teaching Portfolio

"The Teaching Portfolio is by far the most interesting and useful exercise [at UDTU]."
Former participant at UDTU

The Teaching Portfolio is an ongoing document that follows the teacher throughout their teaching career. At UDTU, we encourage our teachers to work actively with their portfolio already during their asynchronous preparation for the first facilitated session, throughout UDTU as part of planned activities, and finally as a product (the UDTU Teaching Portfolio) on which they will be assessed.

The format for Teaching Portfolios at DTU is inspired by the "model for Teaching Portfolio in engineering education" published by the IUS (Ingeniør Uddannelsernes Samråd), a collaboration among all technical universities in Denmark¹³.

The continuous work with the Teaching Portfolio – and the final creation of a UDTU Teaching Portfolio – address the following overall learning objective of UDTU: *Reflect on and continue your development on becoming an excellent DTU Teacher.* On a more specific level, we have operationalised the overall learning objective into the five learning objectives illustrated in figure 5. After the evaluation, defence, and acceptance of the participants' UDTU Teaching Portfolio, they will have reached these five specific learning outcomes.

- Present how your current teaching philosophy informs your teaching practice.
- Reflect on how your perception of teaching and learning has developed over time.
- Show how your ongoing observations of student behaviour and feedback contributes to the development of your teaching practice at DTU.
- Make reference to relevant literature from educational science to describe how you support student learning and develop your teaching practice.
- Demonstrate how collegial observation of your own and your peers' teaching practices influence the continued development of your teaching practice.

Fig. 5 Learning Objectives for the UDTU Teaching Portfolio

¹³ Sass, Ditte Strunge. "UDTU" Learninglab.dtu.dk. Technical University of Denmark. Access date: 05.07.2023 <https://learninglab.dtu.dk/courses-and-events/udtu?accordion=8>

3.2.1 Activities supporting the Learning Objectives of the Teaching Portfolio

During UDTU, we work with an intentional backwash effect, meaning that we begin the programme by showing our participants where they will end. It has been shown that "students learn more and retain their knowledge longer when they engage in deliberate practice focused on clear and specific goals"¹⁴. In practice, we do this at the introduction day of UDTU, when we discuss the two final products on which the participants will be assessed. In terms of the Teaching Portfolio, we ask our participants to watch two short videos that explain the purpose, structure, and assessment of the UDTU Teaching Portfolio. This allows us to do a just-in-time teaching session focussing on their questions, rather than on a presentation of the portfolio with respect to purpose, content, and assessment.

At each subsequent facilitated session, the participants are invited to reflect on the development of their teaching philosophy, choice of methods and teaching practice in different ways – through walk and talk activities, drawings, reflection questions and one-minute papers. We use open reflection time actively to strengthen learning outcomes; participants create an ongoing working portfolio in which they compile a record of their understanding of the methods, models, theories, and activities that they have engaged with throughout the UDTU programme. Asking them to actively reflect on what appeals to them and why, along with what does not, we aim to encourage a high degree of *transfer* of knowledge. The idea about transfer of knowledge was formulated by educational psychologist David Ausubel and refers to e.g., the design of didactical situations that allow learners to learn in a meaningful way, making it possible to activate knowledge in unknown future complex contexts¹⁵.

At our final facilitated session, we set aside time for the participants to give each other 1:1 peer-feedback on pre-prepared UDTU Teaching Portfolio drafts. Based on the formative feedback, the participants revise and re-submit for further anonymous and formative peer feedback within our Learning Management System.

3.2.2 Assessment of Teaching Portfolio

A Teaching Portfolio should not merely document teaching experience or knowledge of educational theory, but rather show competencies. To do so, we ask our participants to produce a *UDTU Teaching Portfolio*, which is a document (max. five pages) that consists of three parts: 1) Teaching philosophy, 2) Teaching methods and 3) Teaching practice description.

To make the document come to life, the participants must focus on the dynamic relationship between the three as they inform and are informed by one another. This dynamic is ensured by including the participants' personal reflective reasoning as they make choices to use (or not use) a certain method/practice and by showing us how feedback from their practice, their students and colleagues influence their development as teachers.

The final product, the UDTU Teaching Portfolio, is assessed at a cluster defence according to a rubric, which is based on the five learning objectives of the Teaching

¹⁴ Ericsson in Felder and Brent *Teaching and Learning STEM*, 25.

¹⁵ Ausubel, David P. *Educational Psychology. A Cognitive View*. New York: Holt, Rinehart and Winston, 1968.

Portfolio. The cluster defences are held four times/year allowing participants to sign up when they have amassed enough teaching experience to reflect on. The defence is a conversation on the strengths and improvement areas in the submitted portfolios. It takes place in clusters of 4-5 participants and is facilitated by educational consultants from DTU Learning Lab. The participants can pass, pass with corrections, or fail and hence re-submit and re-defend their portfolio.

Our intent with the Teaching Portfolio was to create a summative assessment of the knowledge acquired by our participants during their UDTU journey, yet with a flavour of formative feedback as it should point into the future and provide a foundation for their ongoing development as teachers. At first, some participants find it difficult and frustrating to reflect upon their own teaching practice. After completing the UDTU programme, however, they find their Teaching Portfolio and written reflections not only useful for their continuous development as teachers, but also rewarding. Based on the feedback from our participants, we believe the Teaching Portfolio to be a relevant and meaningful product evaluated in a constructively aligned way supported by relevant and meaningful teaching and learning activities.

3.3 Capstone Project

“I have made several changes to my course during my capstone project. Reflecting on these changes, I think the biggest success has been a clear improvement in my active use of learning objectives and the implementation of constructive alignment in every aspect of the course.”

Former participant at UDTU

The Capstone Project is the design of a DTU course (during and between the facilitated sessions), followed by the implementation of the course, testing, collecting data on students' learning outcome and finally evaluating the course in view of future development. The Capstone Project address the overall learning objectives of the UDTU programme illustrated in figure 6.

- Plan, teach, develop, and evaluate student-centred and learning outcome-based teaching at DTU.
- Design a teaching sequence, preferably an entire DTU course, using innovative teaching methods and didactical design to promote student motivation and scaffold student learning and conceptual understanding.
- Design a DTU course using constructive alignment and formative feedback to support students as self-regulated learners.
- Contribute to the development of courses and educational programmes in higher education.

Fig. 6 Overall UDTU Learning Objectives related to the Capstone Project

3.3.1 Teaching and Learning Activities Supporting the Capstone Project

To support participants achieving the learning objectives and ensure constructive alignment, all activities during UDTU have been scaffolded around the creation of the two primary products. On the introduction day of the UDTU programme, we begin by asking our participants to formulate an overarching research question that they will be working on throughout their UDTU journey as they design a DTU course. This could be an overall challenge, problem and/or focus area that they will be researching during their Capstone Project.

All subsequent activities are scaffolded in relation to their research question and the design of their DTU course. Several activities will support them to develop their course directly, as they discover methods and models to apply and test in their courses. Other activities will indirectly influence their design, as they also encounter

methods that they actively do not wish to use. Participants are encouraged to reflect on how choices are informed by, and in turn inform, both their teaching philosophy and the design of their course.

3.3.2 Assessment of Capstone Project

Each participant presents the major findings of their capstone project at a bi-annual poster event. These events are the culmination of all the hard work the participants have put into the UDTU teacher training programme. All DTU employees are invited to participate to be inspired to develop their own courses and teaching.

The posters are pre-approved for presentation by educational consultants in DTU Learning Lab according to a rubric, where the overarching learning objectives for UDTU have been translated into four learning outcomes as illustrated in figure 7.

- | |
|---|
| <ul style="list-style-type: none">- Present a clear research question and the activities you have undertaken to address this in the (re)design of your DTU course.- Analyse, evaluate and reflect on the major findings from teaching your newly designed DTU course with respect to student learning.- Utilize feedback from colleagues and students to improve your teaching and future development as a teacher at DTU.- Participate in higher education discussions on how to develop teaching, learning and educational programmes. |
|---|

Fig. 7 Learning Objectives for the Capstone Project Poster

At the poster event, the participant is assigned a station where to present their poster. In parallel tracks, each participant has ten minutes to present their poster, followed by ten minutes for questions. At the end of all presentations, the audience vote for a best poster. The dean of Undergraduate Studies and Student Affairs presents the award for the elected best poster and gives a closing speech to mark that this is indeed an occasion for celebrating the participants contribution to: the development of teaching and learning and educational programmes at DTU, higher education discussions in general and not least their own development as teachers.

4 SUMMARY

“The UDTU is really fun. A good journey.”
Former UDTU-participant

As mentioned, “The unstated assumption is that if you have a degree in a subject, you must know how to teach it at the college level.”¹⁶ However, if our participants have no teacher training what can and will they do? Other than copy and replicate the least bad teaching they experienced when they were university students themselves. This leads to reproduction of (very) traditional monologue lecturing.

A UDTU-participant stated that he taught very traditionally, before taking part in UDTU: *“I must admit I regret this way of teaching. Not only is this uninspiring, but it also promotes superficial learning and a lack of attention. It is not an understatement to say that UDTU has inspired me to improve!”*

What we have achieved overall, by practicing constructive alignment, is to support and disturb the UDTU participants to focus on their students and the students’ sustainable learning processes and outcome – rather than on themselves as lecturers and the content and their lectures and PowerPoint-presentations.

¹⁶ Felder & Brent *Teaching and Learning STEM*, I.

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