We need to learn how to teach Machine Learning

What are the existing Instructional Designs for introductional Machine Learning courses in the CS bachelor degrees curricula around the world and what can we learn from them for the ML course at TU Delft?

Background

- Machine Learning has been a hot topic for the last decades.
- Continuously growing and gaining more real world use cases.
- Scarcity on professionals with sufficient knowledge of the fundamentals.
- Education is a part of the problem?

Objectives

- Find a list of Instructional Designs used in teaching Machine Learning
- Find (if any) Instructional Designs used in universities but not at TU Delft
- Compare with the courses at TU Delft
- Discover Instructional Designs to use at the TU Delft to improve the course.

Methodology

- Develop a categorization method to identify Instructional designs in course syllabi.
- Research instructional designs of various CS bachelors curricula of different universities.
- Compare to instructional designs at the TU Delft.
- Get feedback from TU Delft ML teaching staff on whether they deem any findings interesting to use at the TU Delft courses.

University	Bachelor
Stanford	Computer Science
Vrije Universiteit	Computer Science
Berkeley	Computer Science
Oxford	Computer Science
University of Virginia	Computer Science
Massachusetts Institute of Technology	Computer Science and Engineering
Technical University of Delft	Computer Science and Engineering

Analysis

- Chosen university courses were analysed in order to determine the use of Instructional designs using the following definitions as basis (The following is a snippet of the data):

Instructional Design Approach	Instructional Design	Definition/What students do
Teacher Centered	Lecture	Instructor presenting material and answering student questions that arise. Students receive, take in and respond
	Interactive Lecture	A lecture that includes 2-15 minute breaks for student activities every 12-20 minutes.

Based on these definitions as categorization method, the teaching material of different universities and manner of assessment the following data was collected:

University	**Stanford**
Bachelor Title	Computer Science
University Type	University
Prerequisites	- Computer Science principles and skills - Probability Theory - Multivariable Calculus - Linear Algebra
Topics extent (Beyond what TUD ML course offers)	- Neural Networks - Deep Learning - Self-Supervised learning - Reinforcement Learning - Decision Trees - Model-based RL - Learning Theory
Assessment	- 40% Assignments (Theory + Programming) - 40% Final Project (In groups) - 20% Midterm
Teaching Material	- (Pre)recorded lectures on Mondays - 1 Lab session on Wednesdays - 1 Homework friday (on campus) - Optional weekly discussion sections led by TAs (interactive/small groups) - Lecture notes
Observed Instructional Designs	**(Teacher-centered/Dirct instruction) Lecture-based:** Weekly lectures introduce the main material
	Project-based/Problem-based/Peer-Assisted-Learning/Field-work: Project is 40% of the final grade
	Case-based/Inquiry-based: Weekly assignements
	Scaffolding (Student-based): Lab sessions where TA's provide help if needed
	Directed Discussion: Discussions in small groups led by TAs

Results

The findings of the analysis was discussed with the ML teaching staff at the TU Delft in an unstructured interview, the following was obtained (The following is a selection of the data collected)

Interesting Finding	Instructional Design	Opinion Type	Teacher 1	Teacher 2	Teacher 3
3% of the grade is class participation at the University of Virginia	Interactive Lecture	Pros	We try to include this in our lectures, sadly sometimes the explanations the teacher has to do run out so there is little time for this. I think this needs to be planned more carefully so there is enough time for it to add value.	If you remove the grade associated with this I would love it, designing our lectures in a way that we focus more on interactivity and having students be more active through the lecture rather than passively listening to what I am saying.	We try to do this during the lecture, sadly not very successfully. Removing the grade from the equation, I am in full support of doing this more often during lectures. I do note that this should be planned better during the lecture so that it gets enough time and focus during the lecture and that it is not rushed through. This allows students to reflect on ideas before revealing the correct answer which could help students understand the ideas better.
		Cons / difficulties	I think having this be a part of the grading is not something we would benefit from, as the ultimate goal we want to have is that students are motivated themselves to take part at learning activities such as this one.	I detest using grades as motivation for students in this way. A student would feel like they are being led into doing this which contradicts the work ethic we want our students to have.	I do not like the fact that students receive a grade for this, I would like it more for students to develop an intrinsic motivation where they are in control of their own learning process
Students of Stanford university go through pre-recorded lecture upon which the physical lecture builds	Flipped Instruction	Pros	I think this is extremely valuable, either you explain concepts and let students play around in the labs which is limited. Or you do it the other way around like it is being done here where you delve deeper with the students	We do this for the more advanced machine learning course where the lecture is already recorded and then you check throughout the lecture where students are stuck and expand from there. This works out very well for students in combination with interactivity in lectures.	I would be interested in knowing whether this is something students like, in that case this could make teaching certain difficult topics easier by breaking them into digestable pieces.
		Cons / difficulties	This could be tricky as some students might not take it seriously and watch the pre-recorded sessions. This is something that teachers need to prepare for from the first year.	Doing this in the first few years of the university career of students, they are not mature enough to follow the instructions by actually watching the material they are intended to watch pre lecture.	This could be difficult to do with a large group of students. From the prespective of students, it feels like the lecture is saying, you have to spend twice the amount of time for the lecture, being a session at home and a session at universities.

Conclusion

After conducting the unstructured interviews with the teaching staff of ML at the TU Delft, a list of instructional designs, which are currently not being implemented in the course at the TU Delft, spring out. The reason is the wide and ease of adaptation in the eyes of the teaching staff. Below is the list of instructional designs.

Instructional Design	Definition/What students do
Interactive Lecture	A lecture that includes 2-15 minute breaks for student activities every 12-20 minutes.
Flipped Instruction	Events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa.
Prior Knowledge Assessment	Entails assessing students' knowledge at the beginning of a unit of work in order to teach students at an appropriate level

Future Work

- Developing learning activities to test the findings from the students perspective.
- Compare to master courses.
- Create a skill circuit using the found results.
-

Ji Darwish
j.darwish@students.tudelft.nl

Supervisor: Gosia Migut
Professor: Marcus Specht

TU Delft