2 Excellence in Teaching

2.1 Teaching Philosophy

Tersely summarized, my teaching philosophy is: *Students learn when students do the work*. Learning is hard, requires energy, and manifests as physical changes in the brain. Short of situations like *The Matrix*, this is not something a teacher can do *to* students. So, what then is teaching? I believe that *teaching is arranging conditions to expedite learning*, and exactly what learning I seek to expedite is influenced by my goals for a university education—to produce independent problem solvers (be they technological, intellectual, or social problems) and to communicate ideas effectively.

In my opinion, an effective teacher explains things at the right time, provides impetus, motivation, and opportunity for students to work, and ensures students are aware of what they do and do not know.

Explaining Things at the Right Time

Good teaching requires a logical order of topics (curriculum) and careful planning around the student experience. Students must be emotionally prepared to engage with the material and when it's time to give an explanation, they must be ready to hear. Below I explain in more detail how this manifests in the classroom.

In graduate school, I was inspired by Eric Mazur's work in physics education, and decided to try teaching my Calculus I course using the "Think, Pair-Share" methodology. This was a *flipped-classroom* approach[1], and it was the first time such a style was attempted in the Sciences at the University of Victoria. The role normally fulfilled by lectures was moved to Youtube videos, but these videos were not the key pedagogical change. The real change was what happened in the classroom. Class time was focused on meeting students where they were: they would work on a question, I would poll the class, and based on the results I would give them more time or guidance or an explanation. The students were more engaged than in a typical math course, and when I gave an explanation, it was different from an explanation in a lecture. Not that the *explanation* was different, but that the context was different. Students, having already struggled with the problem, were ready to see how the framework of calculus could help them, and because I was aware of which conceptual errors they were making based on my polling, I could carefully target my explanations.

Such a drastic change to the workings of a classroom was met with some initial resistance from the students, and preparing the materials for this class took an enormous amount of work. However, it was worth it. I had a collection of students who felt transformed by the experience. One student, who had failed calculus twice before, had been at it so long that he had memorized all the mechanics but somehow missed the concepts. When he encountered my conceptual questions, he was forced to go beyond the mechanics and, with extraordinary effort on his part (he came to all but one of my office hours that term), got an A (a large part was helping this student understand what he did and did not know).

Since then, I've been hooked on active learning. My practices have evolved as I've gained experience. Now, rather than multiple-choice clicker-questions, I use free-form questions. I poll for true/false when appropriate; I ask questions where students draw pictures and write explanations[2]; and I focus on student explanations, often putting several up on the board so we can compare and critique them. But, one thing that has remained consistent is that my explanations of a topic come

[1] I generally try to avoid this term since it has different implications for different people.

[2] I do actually mean *write*. Just "thinking about it" without writing it down is insufficient in my class.

after students have struggled with it.

The results speak for themselves. In a linear algebra course, besides being the top scoring section (out of three sections with common assessments), my students were more willing to attempt problems that had not been explicitly done in class. This was evident from the Matlab projects, one of which asked students to computationally bound the operator norm of a matrix (not phrased in this language). Students in other sections complained that the project was unreasonable, but for my students, attempting something without being told how to do it was just another normal day.

Fostering Motivation

Motivating students with grades or discipline-specific examples is commonplace, and I use these tools. But I have many others, two of which I will outline.

The first is directly talking pedagogy. In a class, I explain my view of how learning happens, how students are smart with big brains, and consequently how challenging it is to avoid rote memorization (for this I have an inspiring analogy involving neural networks). I explain how the feeling of struggle and frustration is actually the process of their brain rewiring itself and that they should be suspicious if they think they are learning something but are not feeling that struggle.

Secondly, I leverage cognitive dissonance. When a student feels they understand something and are then presented with contradictory evidence, they can't help but obsess over the discrepancy. My in-class exercises and problem sets are based on this principle: they start out building an intuitive foundation and then present students with questions that almost (but don't quite) fit with what they might expect[3].

Student Awareness of what they do and do not know

Well-designed assessment is essential for helping students gauge their progress, and asking students to explain their techniques is a stepping stone to the self-evaluation required of independent problem solvers. In office hours, I do this in an individualized way. In classes, I rely on group/peer discussion or written work. For example, every year students claim to understand linear independence, and so I ask them to write down the definition. After struggling, their assessment is: "well, I can't write it down, but I'd know it when I see it." My job is then to convince them that mathematically, they only *know* it when they know the definition.

Lastly, I will mention that sometimes students need to be explicitly told that they know something. Especially when students are learning by guided discovery, after they solve a problem, they may feel like because the instructor did not lecture it, they did not learn. At this point, it is important to be explicit about what they achieved with their effort, and what they can do now that they could not before.

Conclusion

As cliché as it is, I enjoy teaching for its reward and challenge. The satisfaction of seeing someone grasp a beautiful idea or helping someone develop a new way of thinking about the world somewhat uniquely comes from teaching. The very best way to accomplish this under the constraints of a university setting is contested and by all accounts unknown, but I approach this challenge head on in hopes of being the best educator I can be.

[3] To me, this is a step beyond *scaffolding*. We're not just building up to more complicated questions, we're challenging prior assumptions.