My Experiments and Experiences in Teaching

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1 Teaching Style

As a student, I had witnessed different teaching styles. At one extreme, there were teachers who had a precise idea of what they wanted to achieve in a class and had planned the lecture in great detail. At the other extreme, some teachers were largely extempore and banked a great deal on class participation.

Until about 3 years ago, I had not explicitly studied any literature on teaching. Instead, I depended on my instincts and learnt from experience. When I started my career, in my department it was common practice for faculty to attend each others' classes, so I learnt a great deal from colleagues' remarks, ranging from basics like good use of the blackboard and paying equal attention to all sections of the class, to issues such as precise use of terms.

At the start of my career, I used to teach large programming courses at the institute level and core courses in the department. In programming courses I used to plan my lectures very minutely, even planning my board work in advance because I had to write complete programs on board. I had very little interaction in class, but it did not matter much because regular tutorial sessions were available. Core courses in the department had small classes and involved mastering of a large number of concepts. I soon realized two things—that students get a deeper understanding of a subject by developing a clear conceptual base, and abstract models were useful in imparting conceptual clarity. To ensure that students got the concepts right, I strived to make my classes interactive by conducting a lecture as a long dialog with students and permitting them to ask questions at any time. As instructor, I found such dialogs very strenuous, but also effective.

My teaching style evolved over a period of time through experience. I learnt by analysing my experiences in class, deciding what worked well and what did not, and speculating about causes of both. Technological development—particularly PCs, public-domain software and the Internet—impacted education in all disciplines. However, it impacted computer science courses more drastically because many students develop wrong notions and biases about software concepts through the Internet and as computer users, and bring that baggage to their study in computer science. So the instructor

has to retrofit concepts to the large amount of information that a student possesses and slowly dispel the misconceptions and biases. This is a very difficult task. I developed my own teaching style to perform this task and called it the *concept-based* approach to teaching. In this teaching approach, one develops a generic schematic by using fundamental concepts and abstract models and explains working of real systems by using this generic schematic. This way, students understand how to analyse features of a real system by using fundamental concepts and abstraction. This understanding helps them in design.

1.1 Painful Lessons in Teaching

1. *A very logical presentation of material is often lost on students, they only note some features and properties you talked about and ignore the rest:* I have had this experience several times in my career. To get some idea X across to students, I would pre-plan a step-by-step, logical explanation which would motivate the properties of X and show the beauty of X. In my mind, the logical explanation was not just pedagogy, but it was the essence of the subject matter. It seemed to work well in class; however, I later realized that both the logical explanation and the beauty of X was lost on students. They merely noted that X had the properties that I had mentioned in class.

   Remedy: Do not overplan how you would present the logic and beauty of a topic. Develop the topic with the help and participation of students.

2. *Open book examinations may have weaknesses:* Open book exams were an article of faith in the CS courses of 1970s. I used to warn my students that I cannot be asking them recall kind of questions or querying their understanding of first-level concepts in an open book exam. Instead I would be asking advanced questions that involved application of the fundamentals. Class performance in an open book exam was rarely satisfactory. However, I consoled myself saying that I had asked only advanced questions, and students might actually be ok in fundamentals. One day, during a discussion with some students, I realized that they had completely ignored the fundamentals because they would be carrying the book to the exam! The next batch did something similar.

   Remedy: Do not give open book examinations with very high expectations. Either give closed book exams and ask a mixture of basic

and advanced questions, or give open book exams but also find an innovative way to query their mastery of fundamentals.

3. *Do not depend on slides too much:* I used to spend enormous amounts of time and effort in preparing good slides. In class, I would give students enough time to copy the material from slides. However, I found that students were not learning too well because a slide presented "ready" material which contained all details; the details were not developed step-by-step in class so students could not recall the details readily. By comparison, students showed better proficiency in topics for which I did not have slides (and were taught using the board).

   Remedy: Use slides judiciously. A good use is to present a summary of the topics covered in a previous class, or to display complex diagrams that were developed in a previous class. Supplement what is on the slides through some discussion and/or board work.

2 Class Participation

I like my classes to be interactive. So in the first lecture of a course I make an announcement that students are permitted, and even encouraged, to make interesting points and ask doubts and questions freely during a lecture. It enables me to get an idea of how well they are understanding a topic and what they are thinking in a class. Typically, only about one fourth to one third of the students ever speak in class. However, I have never made any specific attempts to make everyone speak for fear that diffident and/or deficient students may resent being put on the spot. When interaction is poor, I seed a discussion by asking some questions. Again, only a small fraction of students answer. But I stretch the discussion on a question as much as possible so that different viewpoints and many right and wrong answers emerge.

When class strengths were small, I used to have mini-tutorials during a lecture—give a question or problem and walk around to see how students were tackling it. It has become harder in large classes.

2.1 Specific Efforts to Enhance Class Participation

1. *Asking students to formulate concept-based questions on material used in a lecture:* I borrowed this technique from one of my colleagues. In the very first lecture, I divide the class into 10 groups. A lecture is allocated to a specific group. The group is expected to formulate a

concept-based question concerning the material covered in the lecture. Students are told that the question should not be a recall kind of question. We discuss the question based on the previous class at the start of the next class. This scheme typically works very well for the first 10 lectures, less well for the next 10 lectures, and stops after mid-semester. As interest dwindles, I allow it to die down. Some groups have difficulties formulating concept-based questions. So if a question is a query for information or facts, I highlight how the information or fact can be deduced from relevant concepts. This is just to illustrate a point made early in the course, that if one has conceptual clarity, details can be worked out.

2. *Fixed seating arrangement and group thinking in a class:* I make groups of 10 students. I pose a question in class and require each group of students to discuss it and formulate its answer. To have stability of groups across lectures, I fix every student's seat in class. Now, a student has the same set of neighbours every time, which facilitates group thinking. To conserve time and retain freshness of the group thinking experience, one can afford only a small number of such interactions in a course. But I have experienced an increase in student interest when I used this technique

3 Critical Thinking

In late-1990s, I noticed that students were "not able to think effectively." I first noticed it in exams. Following the classical philosophy of setting a question paper, I used to have three kinds of questions in an exam—elementary questions, medium-complexity questions, and advanced questions. However, to my dismay I found that the number of students who could tackle advanced questions was dwindling. So I had to tone down the challenge and complexity level of questions. Later I noticed that even elementary and medium-complexity questions were not answered well. When I classified the total marks I was awarding to questions into *deserved marks* and *grace marks*, I found that the grace marks were a significant fraction of the total marks. (I award grace marks if the use of the correct word or term in an otherwise incoherent answer makes me think that the student might have the knowledge but may be unable to express it. I know many/most instructors do likewise.)

So I decided to address this issue explicitly. I spent some time in the first lecture of a course on the basics of *critical thinking*. Starting with the

wiki description "critical thinking is purposeful and reflective judgement about what to believe or what to do in response to observations, experience, verbal or written expressions, and arguments", I described the importance of critical thinking in academics and professional life. I also decided to give explicit weightage to critical thinking abilities of a student in deciding her grade. Basically, the idea was to compute an "overall performance index" based on total marks earned in exams, and a "thinking index" based on marks scored in questions that are specifically marked as *thinking questions* in an exam, and validate the overall performance against the thinking index. If the thinking index was smaller than the overall performance index, it implied that the student was getting some marks undeservedly. So I would lower the grade of the student.

3.1 Painful Realizations Concerning Critical Thinking Abilities of Students

1. I realized that if I consider advanced questions as thinking questions, there would be disaster because very few students were able to tackle them. So I identified some of the medium-complexity questions as thinking questions. I evaluated them very strictly, so that students would not get any grace marks. In 2009-2010, I found that 26.7% students had thinking index $<$ overall performance index. In such cases, I considered the average of overall performance index and thinking index for grading. Consequently, 6.6% students suffered grade losses of one or two letter grades.

2. When I analysed the experience of 2009-2010 a few months later, I came to the conclusion that the deficiency had deeper roots—I found that most students are unable to express themselves coherently and comprehensively, and were mostly unaware of this deficiency because they could get good grades even without thinking or expressing themselves clearly.

   Therefore, during academic year 2010-2011, I decided to focus on "critical thinking" abilities instead of the more demanding "thinking abilities". In this changed perspective, I did not design special questions to test students' thinking abilities. I simply picked some questions that required students to reason at a somewhat elementary level but express their thoughts clearly and coherently. These questions were simpler than the corresponding questions during 2009-2010.

   The experience with this approach (including one student who was

given a re-exam on medical grounds) was even more dismaying—31.7% of the class had a thinking index < performance index. Now 8.3% of the class suffered grade losses of one or two letter grades.

Remedy: The remedy would be to emphasise importance of critical thinking and good expression very early in the B.Tech. program.