# From Teaching to Learning through Coaching (TLC) – Experience from Three Master Level Engineering Courses

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## Abstract

There is a well known proverb about leading horses to water but not being able to make them drink. There is a similar situation with university teaching, where we can design our courses for learning rather than teaching, but still be unable to make the students learn. I have added a step which could be called "coaching" to three of my courses, with somewhat different approaches, and for different reasons. The coaching involves setting clear grading criteria, and selecting tasks of proper difficulty, at suitable time, and giving prompt feedback. My experience is that adding more work for the students, if done with some consideration for the students' schedule overall, will improve learning. They finish more work and with higher grades.

## 1. Introduction

The assessment selected in a course will influence the student's activities. Many times the assessment rather than the formal learning outcomes is regarded as the curriculum. This has been clear to me since I was a student myself, and has been pointed out by several others (Edström et. al., 2005). Although this can be seen as a disadvantage with the system, it can also be used to an advantage. If the written exam checks the knowledge in exactly the most important parts, the students will learn these things. However, not all courses can take advantage of a written exam, and should therefore use other forms of assessment. This is especially the case in courses at the advanced (master) level, where higher levels of skills are trained such as synthesis and design.

I have been teaching courses at the advanced level for several years. When I initially designed the courses it was clear that a written exam was not suitable, and some sort of homework, project or lab work was required. Although the exact nature of the tasks have changed from year to year through incremental changes in course design and changes of the software used in some cases, the aspect of course design which I want to discuss in this paper is that of setting deadlines and selecting tasks that support learning.

## 2. Teaching, Learning and Coaching

The shift from teaching (focus on the teachers' performance in the classroom) to learning (focus on the students' performance, perhaps mostly outside the classroom) has been an important part of pedagogical discussions in universities for as long as I remember, and the main parts are described by Biggs, 1999. However, making the shift effectively as a university teacher is not always so easy. There are also implied requirements from department management to allow more students to pass since this means more money in the current system for distributing funds for teaching. After some attempts at improving my courses in terms of timing and assessment tasks I thought that "Coaching" could be a way to describe the actions of the teacher needed for this shift from teaching to learning.

**An analogy from Sports**
In any sports, at a level higher than the introductory levels for young kids, the role of the coach is to support the development of the athlete by

- Making athletes train regularly
- Selecting harder and harder challenges
- Giving feedback and encouragement
- Encourage team spirit

The role of the university teacher could likewise be stated as

- Making students learn regularly
- Selecting harder and harder homework
- Giving feedback and encouragement
- Encourage teamwork

**But shouldn't this be included in all courses?**
Experienced university teachers who care about their students will probably object and say that this is nothing new, and it is implied by other regulations, or has always been the way courses have been taught by them. I do not disagree, of course this should be the natural order of things, but it is easily forgotten and if not mentioned to the next generation of university teachers, they may have to discover this by themselves after several years of struggling. In the following I share my own experiences in three courses, which will hopefully be of use to other university teachers.

## 3. The three courses, background description

I have developed the following three courses from scratch between 1999 and 2005 and I am still teaching them at KTH (the simulation course also at Fudan U, Shanghai). The courses are updated each year based on student evaluations. All three are offered to master students ("civilingenjör", international master programs and exchange students) and PhD students. The students mainly have a background in applied physics or electrical engineering. I will briefly summarize the main learning outcomes and the type of assessment used in the courses.

**Advanced VLSI Devices aka Design of Nano Semiconductor Devices**
The main learning outcome of this course is that the students, after taking this course, should be able to design a nanometer size transistor, based on a working transistor. In industry, this is done using some simple calculations, computer simulations, and by looking at how others are doing the same thing. When I designed this course I had found a good textbook written by experts at IBM (Taur & Ning, 1998), from which homework exercises could also be selected. Computer simulation labs was an important part from start, and in later versions of the course I also ask the students to look for articles in scientific journals, and present an article of their choice, on a relevant topic for the course, in front of the class.

**Simulation of Semiconductor Devices**
The main learning outcome of this course is that the students, after taking this course, should be able to critically use simulation programs to understand semiconductor devices. This is done by using a combination of common tools from industry (Matlab, Comsol Multiphysics and specialized semiconductor simulation tools), and exploring three different numerical methods (FDM, FEM and FVM[1]). The only way to learn simulation is by running

[1] FDM = Finite Difference Method, FEM = Finite Element Method, FVM = Finite Volume Method

simulations, and the students are required to do this and to write individual lab reports for all the homework. I encourage the students to work two and two, to avoid getting stuck on how to use the computer tools and to have a discussion partner. So far I have not found any good textbook for this course, and eventually I may have to write one myself. There was however a strong need for such a course for the PhD students at our department. Initially I used some simulation programs that could only be accessed by the students in our computer labs, but now I only use software that the students can run on their own computers at home.

**Frontiers of Microelectronics and Information Technology**
The main learning outcome of this course is that the students should learn how to write an essay on the research frontiers on a topic of their choice. For this they need to do their own information searching, and already from start I had decided that peer reviewing would be an important part of this course (Brown, Rust and Gibbs, 1994). The inspiration for this course came from finding the book by Waser (2003), and the course development was done as part of taking the KTH course LU1[2] in 2004. Although the grade is based on the final version of the essay, I require the students to do all other tasks on time and the seminars are compulsory (the students get make up work if they miss individual parts with an acceptable excuse).

## 4. How to set a deadline

This discussion mainly concerns the two first courses where homework was used from start, but not strict deadlines. The Frontiers course had strict deadlines from the start, and the success with these was an encouragement to use deadlines in the other courses as well.

**The incorrect way**
Originally I told the students that "as long as both you and I are alive, I will grade your homework". I suppose my idea was that my being easy on deadlines would make the students happy. It also brought out a few laughs. However, when fewer than 10% of the students ever finished the course, I had to take some action.

**A first step**
As a first step, I set a deadline close to the end of the course, a week or so before they had other written exams to study for. The result was that a much larger part of the students finished the course with passing grades. However, there were still many students who decided to drop the course when they couldn't finish all the homework on time. Because I wanted all homework handed in at one time, the student's still did not spread out their learning but instead waited until the last week.

**The stricter set of deadlines**
I decided to drop the idea of having all homework handed in at one time, and instead I set deadlines every class. I let them turn in the homework slightly late, but deducted points for tardiness. This meant that I had to plan the course better so that the homework was aligned with each week's lectures. After each set of homework I gave them feedback on how they were doing, and told them their grade so far. The extra work for me to keep track of 14-16 individual assignments was not too much, and to my amazement suddenly almost 90% of the students finished the course on time and with high grades.

[2] LU1 = LH201V Teaching and Learning in Higher Education, basic course in university pedagogy at KTH

**A suitable compromise**

After asking the students about their opinion of the course, I made some changes, and I now have one set of homework per week rather than per class session, since they submit homework via email anyway. This reduces the amount of bookkeeping for me slightly, and lets me choose deadlines that work well for the students. I have decided that midnight Monday is a good deadline for several reasons. Students who like to use weekends for homework have all weekend, and students who do other things on weekends still have all of Monday to work on the homework. I also added class sessions at the end of each week (after the lectures of that week) where I am available to answer questions, but mainly the students can use this time to work together on computer simulations on their own laptops.

**Making the students work all the time**

I think there are several reasons why this works well. One reason is that the students quickly get used to having a deadline each week at the same time. The amount of homework is also on a reasonable level to finish during that week, and it is aligned to what I have discussed during the lectures. However, comparing to my old version of the course, the total amount of homework is probably slightly larger now, but still the students manage. Another reason is that the weekly feedback encourages the students to keep working. I am also sure that the students learning is distributed, since they email me something every week. All students that submit the first homework also pass the course, so I am approaching a pass rate of 100%.

Below are tables of how the homework is distributed in the two courses:

Table 1. Simulation course deadlines and grading, fall 2008.

| HW | Points | Matlab | CMP | NanoHUB | Deadline | Content |
|---|---|---|---|---|---|---|
| 1 | 10 | Yes | | | Mon 3/11 | Solution ODEs |
| 2 | 10 | Yes | | | Mon 10/11 | FDM 1D |
| 3 | 10 | | Yes | Yes | Mon 10/11 | Diode |
| 4 | 10 | Yes | Yes | | Mon 17/11 | FDM 2D |
| 5 | 10 | Yes | Yes | Yes | Mon 17/11 | Diffusion |
| 6 | 10 | | | Yes | Mon 24/11 | MOSFET |
| 7 | 10 | Yes | | | Mon 24/11 | FEM, Sch-G |
| 8 | 10 | Yes | | Yes | Mon 1/12 | Transport, Scaling |
| 9 | 10 | | | Yes | Mon 1/12 | Ballistic transport |
| 10 | 10 | Yes | | | Mon 8/12 | Monte Carlo |

| Points | Grade |
|---|---|
| ≥ 90 | A |
| ≥ 80 | B |
| ≥ 70 | C |
| ≥ 60 | D |
| ≥ 50 | E |
| < 50 | Fx |

Homework should be emailed on the date above at 23.59 latest, with your name as filename.

Table 2. Device course deadlines and grading, spring 2008.

| What | Points | Deadline | nanoHUB | Content |
|---|---|---|---|---|
| HW 1 | 5 | Mon 31/3 | - | Basics |
| HW 2 | 10 | Mon 7/4 | - | Scaling/High K |
| HW 3 | 10 | Mon 14/4 | - | SOI/FinFETs |
| LAB 1 | 15 | Mon 21/4 | Yes | Scaling of MOSFET |
| LAB 2 | 15 | Mon 28/4 | Yes | Transport models |
| SEM 1 | 10 | Tue 29/4 | - | Article summary and signup |
| HW 4 | 15 | Mon 5/5 | - | Strain/nano/interconnect |
| SEM 2 | 10 | 6, 8, or 9/5 | - | Seminar: presentation + QA |
| SEM 3 | 10 | Mon 12/5 | - | Written summary of seminar |

| Points | Grade* |
|---|---|
| ≥ 90 | A |
| ≥ 80 | B |
| ≥ 70 | C |
| ≥ 60 | D |
| ≥ 50 | E |
| < 50 | Fx |

* A grade > E requires that the student has some points for each area: homework, labs and seminars.

(Matlab, CMP = Comsol Multiphysics and NanoHUB indicate which software is used)

## 5. Selecting tasks that support learning

This discussion mainly concerns the third course where the students write an essay. Initially I gave the students a weekly quiz to test that they had done their required reading before the class, but I have skipped that part after hearing the students' evaluations that this part was not so good. I also found that requiring other work weekly was a better way to improve the final essay.

**Peer assessment of essays**

Already from start I decided to use peer assessment of the students' essays as a learning tool (Brown, Rust and Gibbs, 1994). Not only do the students learn a lot by giving constructive criticism on each other's essays, but also they get ideas for improving their own essays when reading someone else's work. Because of this peer assessment, the deadlines were strict to start with; otherwise a student might fail due to not having an essay to review. Although most students finished on time, I could tell they started their writing late, and I had some unfortunate cases of suspected plagiarism.

**Avoiding plagiarism**

There are several reasons for plagiarism in student writing (Carroll, 2007). Initially, I though the problem was that the students plagiarized because they thought I wouldn't catch them. Then I added extra information during the seminars on plagiarism, informing them about the rules and how I would enforce them (although I am pretty sure they know plagiarism is forbidden) and I talked a bit about making references to other peoples work. Still there was a case of plagiarism in that course. Now I believe that the problem is the following: the students have little or no practice in writing, so they start late because they can't judge the time needed, and when they run out of time they may plagiarize parts or the entire essay.

**Using warming-up tasks and increasing peer assessment**

My solution to this was to give extra writing tasks each week starting from the first week (writing a preliminary title for their essay, searching for some articles, summarizing the articles, writing an abstract, discussing merits of different references) and adding a second round of peer reviews which forced them to make their first draft much earlier. I recommend extra reading on how to write essays (McMillan and Weyers, 2007). I also tried to discuss plagiarism during the course, and point it out when it occurs in their drafts. Since the drafts are not graded, I do not have to report attempted plagiarism at this point, but I can tell the students that they should do something about it. This latest course had no attempted plagiarism, so I am hopeful about the future.

Below is a table from the Frontiers course spring 2008 which shows how the student learning is spread out by requiring some work almost every week. Feedback is the reviews the students give to each other.

Table 3. Seminars and homework in the Frontiers course, spring 2008.

| Week | Date | Time | Reading plan / Content | Pages | Homework due 10 AM |
|---|---|---|---|---|---|
| 4 | 25-jan | 13-15 | Introduction / Referencing + Plagiarism | | |
| 5 | 1-feb | 13-15 | Gray pages (all sections) / Info searching | 104 | Select topic ("Title") |
| 6 | 8-feb | 13-15 | I Fundamentals / Summarizing | 144 | Article search KTHB |
| 7 | 15-feb | | *No Class Meeting* | | Summary of article 1 |
| 8 | 22-feb | 13-15 | II Technology and analysis / Abstract | 112 | Summary of article 2 |
| 9 | 29-feb | | *No Class Meeting* | | Abstract, keywords |
| 13 | 28-mar | 13-15 | III Logic devices / Feedback 1 | 142 | First draft |
| 14 | 4-apr | 13-15 | IV Random access memories / Different sources | 62 | Feedback 1 |
| 15 | 11-apr | 13-15 | V Mass storage devices / Peer review | 76 | Source criticism |
| 16 | 18-apr | 13-15 | VI Data transmission and interfaces / Feedback 2 | 86 | Second draft |
| 17 | 25-apr | 13-15 | VII Sensor arrays and imaging systems + VIII Displays / Final version | 126 | Feedback 2 |
| 19 | 9-maj | 13-15 | *Essays* | 852 | Final essay |

## 6. The student's learning experience

The student's opinions are very important for course development. I try to get all students to fill in a course evaluation at the end of the course, and sometimes I have given them homework credit for doing so, even though this makes anonymous course evaluations difficult. Asking relevant questions is however difficult, if it gets too detailed the students find that it is too much work to do the evaluation, and asking too open questions might not result in any useful opinions. Already from start the students were positive to having homework rather than a written exam in these courses. Those who passed also found the homework useful, but time-consuming. One student said he had used 200 hours for my course (which is expected for a 7.5 hp course) and that was twice as much as he had used in any other course at KTH. After changing to stricter deadlines I was expecting more complaints, but instead the students were even more positive. The amount of work was no longer a major complaint (although the amount was slightly larger), and the feedback I gave on the homework was really appreciated. A few students even said it was the best course they had taken at KTH. The essay course has also had good feedback except the quiz part I used initially, and the more writing tasks I add the more positive they are.

I think that the problem we have with some courses is not that the amount of work is too large, but that it is not distributed in a fair way for the students. Although you could argue that $4^{th}$ or $5^{th}$ year students should be able to plan their time by themselves at this point, it seems that doing the planning for them by imposing deadlines every week improves the course result in terms of number of students who pass. Judging by the grades they have received from their homework, or the quality of their essays, I also think their learning has improved. I suspect that stating the grading clearly at the start of the course also motivates the students to work harder, since more homework completed means a higher grade for them.

## 7. Conclusions

By adding a step which could be called "coaching" to three of my courses, with somewhat different approaches, and for different reasons, more students finish the courses and with higher grades. The coaching involves setting clear grading criteria, and selecting tasks of proper difficulty, at suitable time, and giving prompt feedback. My experience is that adding more work for the students, if done with some consideration for the students' schedule overall, seems to improve learning.

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Carroll, J., “A Handbook for Deterring Plagiarism in Higher Education”, 2nd Ed., Oxford Centre for Staff and Learning Development, Oxford Brookes University, 2007.

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Taur, Y. and Ning, T., “Fundamentals of Modern VLSI Devices”, Cambridge University Press 1998.

Waser, R., “Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices”, Wiley 2003.

## Course home pages

Design of Nano Semiconductor Devices: http://www.ict.kth.se/courses/IH2657

Simulation of Semiconductor Devices: http://www.ict.kth.se/courses/IH2653

Frontiers of Microelectronics and Information Technology: http://www.ict.kth.se/courses/IT2655

LH201V Teaching and Learning in Higher Education, see http://www.learninglab.kth.se