Pedagogical Innovations

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Upon joining the faculty at UT Austin as an Assistant Professor in fall 1996, my first task was to start developing a brand new upper division course with significant lecture and laboratory components. On my second day on the job, I drove to Houston to attend an educator’s conference to look for ideas for this new course. After a year of frenzied development, I offered the Real-Time Digital Signal Processing Laboratory course for the first time in fall 1997, and have taught the course now more than 25 times. It is an embodiment of my passion for the field.

Here are some of the key pedagogical innovations of the course over the years. I describe many of the pedagogical innovations in the “Statement of Teaching”, which I will repeat here as well.

A significant, recent innovation is the following (underlined text indicates a hyperlink):

- **Open Courseware to Facilitate Self-Study.** In spring 2014, I recorded lecture discussions with students on video, including discussions of homework and midterm #1 solutions, and posted the videos on YouTube for everyone to access. The number of views is increasing at a rate of about 1,200 per month. Along with the videos, I put online all of the course materials (PowerPoint slides and PDF handouts, as well as past and current midterm exams) [3]. This enables self-study of the material by current students as well as other motivated individuals.

Pedagogical innovations based on student feedback include the following:

- **Motivate Every Lecture.** At the beginning of each lecture period, I now describe how today’s lecture topic fits into the course, future electives, graduate study and industrial practice. I add descriptions throughout each lecture.

- **Create Handouts on Pre-Requisite Material.** With student Jean Farias, I created a handout to review the Fourier transform, which is a fundamental mathematical tool in the course. I also created handouts on other pre-requisite topics such as convolution, modulation, and linear time-invariant systems, as well as the co-requisite topic of random variables.

- **Split Homework Assignments.** Changed four homework assignments with five problems each assigned over a two-week period to eight homework assignments with three problems each assigned over a one-week period. Students would often start working on the homework assignment on the Monday before it was due on Friday and simply could not finish a five-problem homework set intended to be completed over a two-week period.

- **Flip the Classroom.** Homework assignments ask students to perform quantitative analysis and interpret the results. Assignments are due in lecture on Fridays. On five Fridays, I flip the classroom by working through homework solutions. I also flip the classroom when returning the midterm #1 exam to discuss its solutions. The problems are very fresh in student minds.
Enable Electronic Note Taking in Lecture. Students in spring 2013 wanted to take their notes on the course reader on their tablets and laptops. I made the course reader available as a free download starting in spring 2013. The course reader has all of the slides, handouts and old midterm exams (most of them with solutions).

Make Weekly Deliverables in Lab Explicit. The teaching assistants and I drafted documents detailing the weekly deliverables for each week of lab work (example).

Finish All Lab Work in Lab Section. Added a pre-lab quiz for each new laboratory assignment based on the assigned reading so that students would be better prepared for laboratory tasks. This allowed students to finish their lab work in the lab section, and not have to come back later in the week or during the weekend.

Decouple Class Office Hours and Drop-In Advising Hours. By decoupling class office hours and drop-in advising hours, students enrolled in my course are not blocked out from asking course-related questions due to other students seeking non-course advice. My weekly office hours are reserved for students in my course. Separate from office hours, I hold weekly drop-in advising hours for all students at a local café.

Find Lecture Time Best For Learning. Upper division students prefer certain timeslots for lecture, e.g. 11am or later. Seniors are up late on Mondays and Wednesdays working on senior design projects. I have tried different days/times and adopted MWF 11am-12pm.

Pedagogical innovations based on observations of many of the difficulties that students faced:

Hands-on Learning. Homework assignments ask students to analyze signals and design signal processing algorithms by writing computer simulations [2]. The assignments are constructed to give immediate sensory feedback in the form of visualizations and/or sound. So, too, are weekly laboratory tasks [2]. This immediate sensory feedback really helps students in refining their designs until they give the desired visible or audible responses. Lab concepts are tightly integrated with lecture topics and homework assignments.

Bridging Application Theory and Software Implementation. Students model digital signals and algorithms as mathematical equations, convert equations to computer simulations in the Matlab programming language, validate and interpret results, implement algorithms in the C programming language on a standalone board, and validate and interpret results. Students quantify design tradeoffs in signal quality vs. implementation complexity in their Matlab and C programs. The implementations give students new insights into the application theory, and students use the insights to develop more efficient algorithms for implementation.

Visual Demonstrations. Give computer-based demonstrations of lecture concepts at least twice a week. Students can also run them. Demonstrations on convolution, sampling, filter design, filter analysis, image processing, video recording, and communication systems.

Reviewing Pre-Requisite Material in Lecture. Changed the initial version of the course in which students hit the ground running to spending four weeks reviewing pre-requisite material while discussing new applications of the material being reviewed to give a larger picture of the material. Many students took the pre-requisite courses 1-2 years ago.
• **Rapid Feedback for Rapid Learning.** The eight homework assignments are due on various Fridays of the semester. When the student turns in the homework assignment, I immediately hand them the solution set, which is also available online. Each homework assignment is graded with feedback and returned to the student by the next lecture (Monday). Midterm #1 is given on a Friday, and it is also graded by the next lecture (Monday) with the solution set.

• **Multiple Views.** The course lies at an intersection of mathematics, computer science and engineering. For each major topic, I provide three analysis views—time domain, frequency domain and generalized frequency domain (Laplace and z domains). For each view, I present mathematical tools, 2-D visualizations, and animations. For example, I show how to create a chorus of the same instrument from one instrument playing by taking the audio signal, delaying it by varying amounts of time and adding up all of the delayed versions. Another example is the sampling demonstration (starts at the 47:39 mark).

• **Bringing Research into the Classroom.** I bring graduate-level research project results into lectures, homeworks and exams. In lecture 4 on sampling and aliasing, I play videos of the handshake distortion when recording video on smart phones and show the videos after applying our methods to correct for handshake [2]. In lecture 12 on channel modeling, I give examples of challenges in communicating information through air, wires, and water [2].

• **In-Class Examinations.** The two midterms are open notes, open books and open laptops, but closed Internet or other network access. The idea is to give the students the same environment as they had when working homework problems, except that network access cannot be granted to avoid possible academic dishonesty. Each midterm has four problems. Problem #1 is based on fundamental principles that were emphasized on homework problems. Problems #2 and #3 test critical thinking by asking the students to derive new equations and relationships and offer explanations and interpretations of the derivation. Problem #4 tests critical thinking using qualitative analysis in an argumentative essay.

• **Extensive Course Alumni Network.** The alumni list was started initially to show the impact of the students on companies and graduate programs in order to justify the use of the graduate teaching assistantship funds for the course. The alumni list quickly became useful to current students in the class not only to connect with companies for internships and full-time positions but also find out more about graduate studies from alumni in graduate schools. The successful placement of students in industry and graduate study also helped motivate them.

**References**

http://users.ece.utexas.edu/~patt/Ten.commandments/

http://users.ece.utexas.edu/~bevans/courses/realtime/index.html