How to Teach Signal Processing

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Why am I giving this talk?

Why do Researchers Teach?

“If you can’t write it, you can’t think it.”
— Shigeo Hasegawa

Clarity of communication enforces clarity of thought.
Outline

1. The Research-Teaching Nexus

2. How to Teach
   - Skills
   - Goals
   - Plans
   - Communicate
   - Involve
   - Reinforce
   - Learn

3. Summary
Does Research Aid Teaching?


In principle, the research-teaching nexus relates to ways in which research supports teaching and teaching supports research. In practice, the discussion has been limited almost entirely to the first of these issues, and it will be in this study as well...

Studies reveal no significant correlation between faculty research and effective teaching.

Attending a college whose faculty is heavily research-oriented increases student dissatisfaction and impacts negatively on most measures of cognitive and affective development.
Research has the *Potential* to Aid Teaching

“A paradigm shift is taking hold in American higher education,” from “a college is an institution that exists to provide instruction” to “a college is an institution that exists to produce learning” (Barr & Tagg, 1995). In this paradigm, “What professors do in their classes matters far less than what they ask students to do” (Halpern and Hakel, 2003).

— [http://serc.carleton.edu/NAGTWorkshops/careerprep/teaching/learning.html](http://serc.carleton.edu/NAGTWorkshops/careerprep/teaching/learning.html)
OK. But does Teaching Aid Research?

Using a performance rubric, we compared the quality of methodological skills demonstrated in written research proposals for two groups of early career graduate students. After statistically controlling for preexisting differences between groups, students who both taught and conducted research demonstrate significantly greater improvement in their abilities to generate testable hypotheses and design valid experiments.

Impact: Another Way in which Teaching Aids Research

http://en.wikipedia.org/wiki/Plato

He founded the Academy in Athens, the first institution of higher learning in the Western world... Whitehead once noted... the European philosophical tradition... consists of a series of footnotes to Plato.

http://en.wikipedia.org/wiki/Pythagoras

The lack of information by contemporary writers, together with the secrecy which surrounded the Pythagorean brotherhood, meant that invention took the place of facts. Pythagorean ideas exercised a marked influence on Plato, and through him, all of Western philosophy.
Was Einstein a Good Communicator?

The Annus Mirabilis, 1905


- **Brownian Motion:** “On the motion of small particles suspended in a stationary liquid, as required by the molecular kinetic theory of heat.” Einstein, *Annalen der Physik* 17(8):549-560, 1905

- **Special Relativity:** “On the electrodynamics of moving bodies.” Einstein, *Annalen der Physik* 17(10):891-921, 1905

- **E = mc²:** “Does the inertia of a body depend upon its energy content?” Einstein, *Annalen der Physik* 18(13):639-641, 1905
Research and Teaching are Largely Independent Skills . . . (Prince, Felder & Brent, “Does Faculty Research Improve Undergraduate Teaching?” JEE 96(4):283-294, 2007)

<table>
<thead>
<tr>
<th>Excellent researchers must be...</th>
<th>Excellent teachers must be...</th>
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<tr>
<td>observant, skilled at drawing inferences, &amp; tolerant of ambiguity.</td>
<td>skilled communicators, familiar with the conditions that promote learning and expert at establishing them, approachable &amp; empathetic.</td>
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Researchers who teach demonstrate greater improvement in their abilities to generate testable hypotheses and design valid experiments (Feldon et al.)

- Clarity of communication enforces clarity of thought.
- If you can’t write it, you can’t think it.

Researchers who communicate effectively and broadly have greater impact.

- Pythagoras vs. Plato
- Einstein
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“How to Teach,” *WikiHow*, article originally authored by Melissa Ganus in 2006
### Summary: How to Teach

1. Identify crucial skills.
2. Set goals.
3. Develop lesson plans.
4. Engage students.
5. Allow independent exploration.
1. Identify Crucial Academic Skills

Think about what skills your students will need to employ in order to make it through elementary school...
How you can
1. Identify Crucial Academic Skills in the preparation of your signal processing presentation

By the end of this talk, my audience will know how to...

- adapt an automatic speech recognizer to a new voice using eigenvoice decomposition
  ...or...

- train SVMs to detect acoustic landmarks
  ...or...

- rescore an acoustic event detector using an i-Vector dichotomizer
  ...or...
Now that you know what you want your students to be able to do, outline the smaller skills which will be necessary to get them to those larger goals.
2. Set Goals

In order to detect acoustic landmarks, my audience needs to understand

- **WHY** would one desire this skill? e.g., *derive* it from
  - biomimetic justification
  - information-theoretic justification
  - optimization of a useful criterion

- **HOW**? What is the *algorithm* by which one practices this skill?
  - Describe the algorithm mathematically
  - Draw a flowchart or signal flow diagram

- **WHAT** are the *applications* of this skill?
  - Examples: describe experimental setup
  - Examples: show pictures of individual signals
3. Develop Lesson Plans

Ganus et al., 2006-14

Now that you have your educational roadmap, make a lesson plan which specifically lists how you will get them to each step in that road.
3. Develop Lesson Plans

- How long is your talk? Number of slides ≤ number of minutes.
- The rules of good presentation. Nobody in your audience will read:
  - ... anything written in < 20 point font
  - ... anything past the third label on a graph, third symbol in an equation, or third item in a list
  - ... anything at all if the slide is up for less than a minute.
- Structure of the talk: (1) Tell ’em what you’re going to say, (2) Say it, (3) Tell ’em you said it.
4. Engage Students

Ganus et al., 2006-14

Use visual aids and multiple representations of concepts... concrete, non-linear, multiple forms of experience and uses of data, and examples of the things which you are discussing.
4. Engage students

- Use visual aids and multiple representations of concepts... *(equations)*
- ...non-linear, multiple forms of experience and uses of data... *(pictures)*
- ...and examples of the things which you are discussing. *(story)*
Story: examples of the things which you are discussing

I recommend:

The Heath& Heath formula for stickiness

Simple | 1 idea
Unexpected
Concrete | formulaic except...
Credible | time, place, names
Emotional | citations!
Stories | protagonist/antagonist
Stick

— Made to Stick: Why Some Ideas Survive and Others Die, Chip Heath and Dan Heath
5. Allow Independent Exploration

Ganus et al., 2006-14

Let them experiment. Allow for creative interpretations of assignments. Encourage innovation. Give them broad assignments with specific goals and let them come to their own method of reaching that goal.
Socrates: And this space is of how many feet?
Boy: Eight feet.
Socrates: And from what line do you get this figure?
Boy: From this... the line which extends from corner to corner of the figure of four feet.
Socrates: And that is the line which the learned call the diagonal.... What do you say of him, Meno?... at present these notions have just been stirred up in him, as in a dream; but if he were frequently asked the same questions, in different forms, he would know as well as any one at last?
Socratic Method: Fanfic Improvements of the Meno Argument

Plato’s derivation of the Pythagorean theorem

https://www.youtube.com/watch?v=ajuU0h0lxY
5. Allow Independent Exploration

But what happens if you’re at ICASSP, in front of a large audience, and the Socratic method is impractical?

How can you encourage audience participation from an audience unwilling to speak?
6. Reinforce Learning

Occasionally revisit old material. This will solidify and reinforce the skills that a student has gained, much like learning a language requires study every day.
6. Reinforce Learning

Edwin Diamond, Professor of Journalism, New York University, 1925-1997

Journalism is Life, just more so.

Ed Diamond taught a 1996 course in “Politics & the Media” at MIT. He said that journalism is “a continuous means of asserting oneself as a human being, and an agent of the world.”

Ed Diamond’s Aphorism on Reinforced Learning

“If you want anybody to remember what you say, then you need to say it at least three times. Tell ’em what you’re going to say; Say it; then Tell ’em you said it.”
11. Keep Learning

Read up on your craft. Read the latest journals and papers from conferences to keep up with the most innovative methods and new ideas regarding technique.
Job Description: Student

Learn.
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Summary: How to Teach

1. Identify crucial skills.
2. Set goals.
3. Develop lesson plans.
4. Engage students.
5. Allow independent exploration.
Summary: How to Give an Effective Presentation

1. Identify crucial skills.
   - What will your audience be able to do, once they’ve heard your talk?

2. Set goals.
   - What fundamental understanding is necessary in order to acquire this skill?

3. Develop lesson plans.
   - What logical steps must they follow to acquire understanding?

4. Engage students.
   - Each step: In what 2-3 forms will you describe it?

5. Allow independent exploration.
   - What problems will be left for the audience to solve on their own?