Listening to students in upper-division physics courses

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American Physical Society
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Philosophy

I. Listening to students is the FUN part

II. All the things that work in intro physics also work in advanced physics, because people learn the way people learn

III. Mathematics is a conceptual expression of the physics, but students need to learn that.

IV. Classes are smaller, engagement is more intense, students are human, and you are, too.
Consider placing a steel wire in an open circuit; what happens when a paper clip is placed across open leads from a battery?

Inter.: How do [electrons in the steel wire] move?

Thomas: … Just the ones on the most outer shell would move. They’d get pulled off the atom.

Inter.: And how do they get pulled off the atom?

Thomas: By the electric field. It attracts them and pulls them away from the positive nucleus of the atom.
How does conduction work in this case?

David: Electrons get out from one atom... This electron takes the place of this electron here, this one takes the place of this one, and then this one, ... [The electron] comes again out of the atom and it moves to the next one.”
Students build comparisons

What about doped substances - what effect does this have?

Thomas: I think the doped ones are better conductors because I think it takes a lot of energy to remove the silicon electrons, but if you add electrons from a different metal, like aluminum, which require less energy to be removed, then you’d get more current using less energy.
LISTEN TO YOUR STUDENTS

They’re really good at sense making with too little information.
You need to help them with that.

(Also: find someone else to talk to about the things you hear.
It’s super important to have colleagues who can reflect your curiosity back at you.)
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II. A smorgasbord of teaching

• Teach in the ways that work best for you. Plural.

• Use methods shown to be successful at the introductory level

• Create and adapt materials as needed.
Use what works - be creative!

For a junior level quantum course, we used:

• Lecture *and* Tutorials, mixed in various ways.
• Just-in-Time-Teaching web essay assignments
• Applied physics homework assignments
• Simulations, sensors, interactive programs, etc.
• Examination questions with conceptual questions, not just mathematics (plus… essays!)
Connect basics to bigger things

You can use real examples to teach basic QM, rather than using abstract math problems.

Talking about X lets you talk about Y

• photoelectric effect → photomultiplier tubes
• LEDs and conductivity model → diodes
• Quantum tunneling → scanning tunneling microscopes
Things I’ve done:

- **QM:** interactive lectures, tutorials, JITT, simulations, applied examples, conceptual exam questions

- **Classical mechanics:** Overview Case Study, interactive lectures, tutorials, JITT, simulations, Group Problem Solving, flipped classroom

- **Math methods:** flipped classroom, group problem solving
How to flip - the case for math
How to flip - the case for math

\[ x(t) = A \sin \left( \frac{2\pi}{T} t \right) + B \cos \left( \frac{2\pi}{T} t \right) \]

\[ x(t) = C e^{rt} \]

\[ C e^{rt} + C e^{rt} = 0 \]

\[ r = \pm \sqrt{\frac{\omega^2}{k} - \frac{1}{4}} \]

\[ x(t) = C e^{rt} + C e^{-rt} \]

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Remember who you are teaching, not the best in the class, but the whole class.

Go slow. Be careful. Give reasons. Unpack the math carefully.

Help them see what you see and how you learned to see it.
Job #2

BUILD ON WHAT WORKS

We know a lot about good teaching. Use it.

(Also: find someone else to talk to about your teaching. It’s super important to have colleagues who can observe and improve your exploration.)
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Mathematics and meaning

Let’s start with a typical TLE. What does the equation “F=ma” mean?
Developing meaning from math

• Let’s do some of a tutorial in classical mechanics…
Reflection

• What did you notice?

• Where do you think your students will struggle?

• What will your students bring to the class that helps them succeed?
Job #3

GO DEEP ON THE MATHEMATICS, BUT SLOWLY

They have to learn how physics finds meaning in math.

(Also: find someone to talk to about this transition. It’s super important to think about what students have done before and they will do next.)
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Being human, in all its richness

• Small classes are chances to truly get to know your students

• They are developing their identities as physicists

• They are novices but not beginners

• They are wonderful human beings

• So are you - meet them in this place as a mentor and a guide
Reflection

• Students want to see a pathway. What parts of you might offer that path?
Job #4

BRING YOUR SELF INTO THE CLASSROOM

They need it.

(Everyone has that teacher that they remember. Try to be that person to at least some of them, all the time.)
Philosophy

I. Listen

II. Build on the known

III. Add meaning to math

IV. Be human
Physics Teaching

Get the Facts Out

PhysTEC Physics Teacher Education Coalition

Leadership

Thriving Depts.

EP3 Effective Practices for Physics Programs

APS Community

COE    EPC
Grad Ed  FEd  GPER

NPRLG NSF Physics REU Leadership Group

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