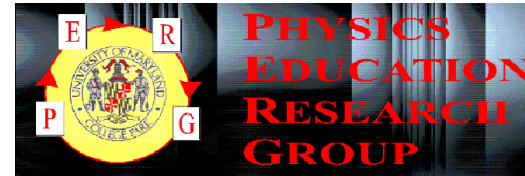


# Analyzing Student Expectations of Physics in a Modified Quantum Physics Course\*

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# The role of student attitudes in teaching physics

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## Example Goal:

Have students see quantum mechanics as relevant to their future work and studies

## Effect on curriculum design

- Focus on device-based approach
- Build simple conceptual models which are relevant now, not later.

## Effect on teaching

- Emphasize connections to the real world
- Build bridges to previous knowledge (classical physics or previous engineering topics)

# New Model Course in Applied Quantum Physics

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## Motivation

Scientists and engineers will be using many tools and devices that are fundamentally quantum in nature:

- *Transistors*
- *SQUIDs*
- *Lasers*
- *MRI*
- *STM*
- *...*

Traditional QM courses are not well matched to non-physics majors.

*A New Model Course in Applied Quantum Physics:*

URL: [www.physics.umd.edu/perg/qm/qmcourse/](http://www.physics.umd.edu/perg/qm/qmcourse/)

# PER based conceptual & device approach

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- Real examples used to teach basic QM rather than abstract math problems.
  - photoelectric effect → photomultiplier tubes
  - LEDs and conductivity model → diodes
  - Quantum tunneling → field emission microscopes
- Reliance on physics education research:
  - design
  - refine
  - evaluate
  - ... (re)<sup>n</sup>design, (re)<sup>n+1</sup>fine, (re)<sup>n</sup>evaluate

# Modular course design

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- Tutorials  
Modeled after UW-style tutorials<sup>1</sup>
- Just-in-Time-Teaching<sup>2</sup> web essay assignments
- Applied HW  
Based on our experience with alternative homework assignments (AHA) in the Activity Based Physics Project<sup>3</sup>
- Software  
*Visual Quantum Mechanics, Photoelectric Tutor, physlets, MBL, spreadsheet physics, CUPS, MUPPET...*

<sup>1</sup> L.C. McDermott, P.S. Shaffer, and the Physics Education Group at the University of Washington, *Tutorials in Introductory Physics*, Prentice Hall, Upper Saddle River, NJ, 1998.

<sup>2</sup> G.M. Novak, E.T. Patterson, A.D. Gavrin, and W. Christian, *Just-in-Time-Teaching: Blending Active Learning with Web Technology*, Prentice Hall, Upper Saddle River, NJ, 1999.

<sup>3</sup> E.F. Redish and the Physics Education Research Group, University of Maryland. Materials available on the web at <http://www.physics.umd.edu/rgroups/ripe/perg/abp/aha/>.

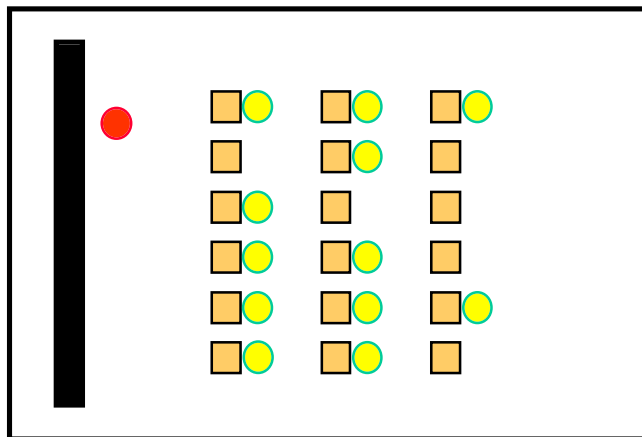
# Modified course

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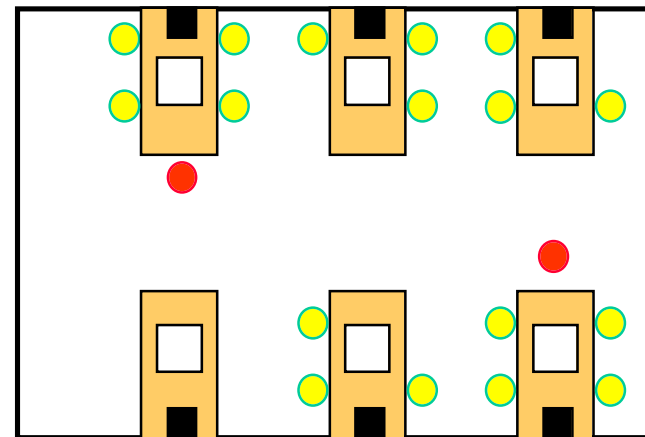
Modified, junior level quantum physics course for scientists and engineers:

- Lecture: 2 hours / week
- Tutorial: 1 hour / week  
UMD-developed tutorials which often make use of appropriate software packages
- Class assignments: JITT essays due each morning before class

**lecture setting:**



**tutorial:**



# Conceptual learning in modified setting

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Measured improvement in student learning of:

- tunneling
- conductivity
- interpretation of the wave function
- photoelectric effect
- ...

(Compared to traditionally taught courses for scientists and engineers)

Results reported at previous AAPT meetings (1997-present).

# Reality-link JITT essay questions

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## Questions about location:

– Feb 7:

In classical physics, we often talk about the location of a particle.

How do we know the location?

List a few methods of measuring where a particle is located.

– Apr 7:

Is it possible to measure the location of a single atom? Explain...

## Questions about measurement:

– Feb 23:

We often talk about the “probability” that something might happen. Give some examples from real life, and some examples from physics (e.g. what is the probability that a thrown ball will be within 5% of its peak height?).

– Mar 10:

You have a friend taking a class like this one at another school. She says, “We just talked about the probability of finding particles in a potential well, and I think I figured it out. Whaddya think, the particle is always located somewhere, but we sometimes simply can’t measure it. Even if we’re not always paying attention to it, it’s still located somewhere, right? That makes sense to me...”  
What do you tell her? Do you agree? disagree?

# Device-oriented essay questions

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## Discussing applications of the physics:

- An LED is a device like the one in your VCR remote control. When observed, it seems to shine in only one color. Is there a filter in the glass, or is it a property of the device? Explain how you could account for the observations based on what you know about the device.

## Student responses:

- I've never thought about it before... it could be that the LED is being excited at a specific frequency, such that the resulting wavelength is associated with a specific color of light. ...
- I'm pretty much guessing here... The light emitted from an LED is due to the potential drop across it - just like an ordinary resistor emits heat due to the potential drop across it. ...
- I have seen many LEDs when they are not on and the color that they have when they are off is the color of light they give off when they are on. Therefore it must be a filter in the glass that gives it its monochromatic light.

# Maryland Physics Expectations Survey (MPEX)

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- E.F. “Joe” Redish, Jeff Saul, Richard Steinberg
- 34 question Likert-scale diagnostic test
- Investigates student attitudes and expectations toward the course.

Administered to two populations:

- modified course for scientists and engineers
- traditional physics majors course in QM

post-test only, no pre-tests!

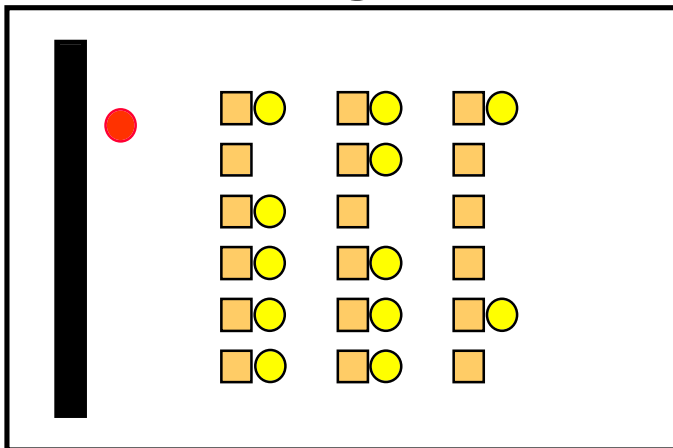
# Comparison physics majors QM course

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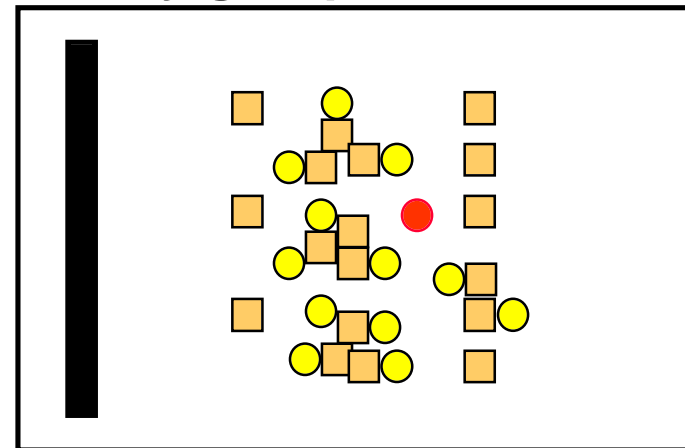
Traditionally taught quantum mechanics majors course:

- Lecture: 3 hours / week
- Weekly recitation: 1 hour / week  
Problem solving session focused on developing mathematical methods presented in class.

**lecture setting:**



**weekly group work session:**

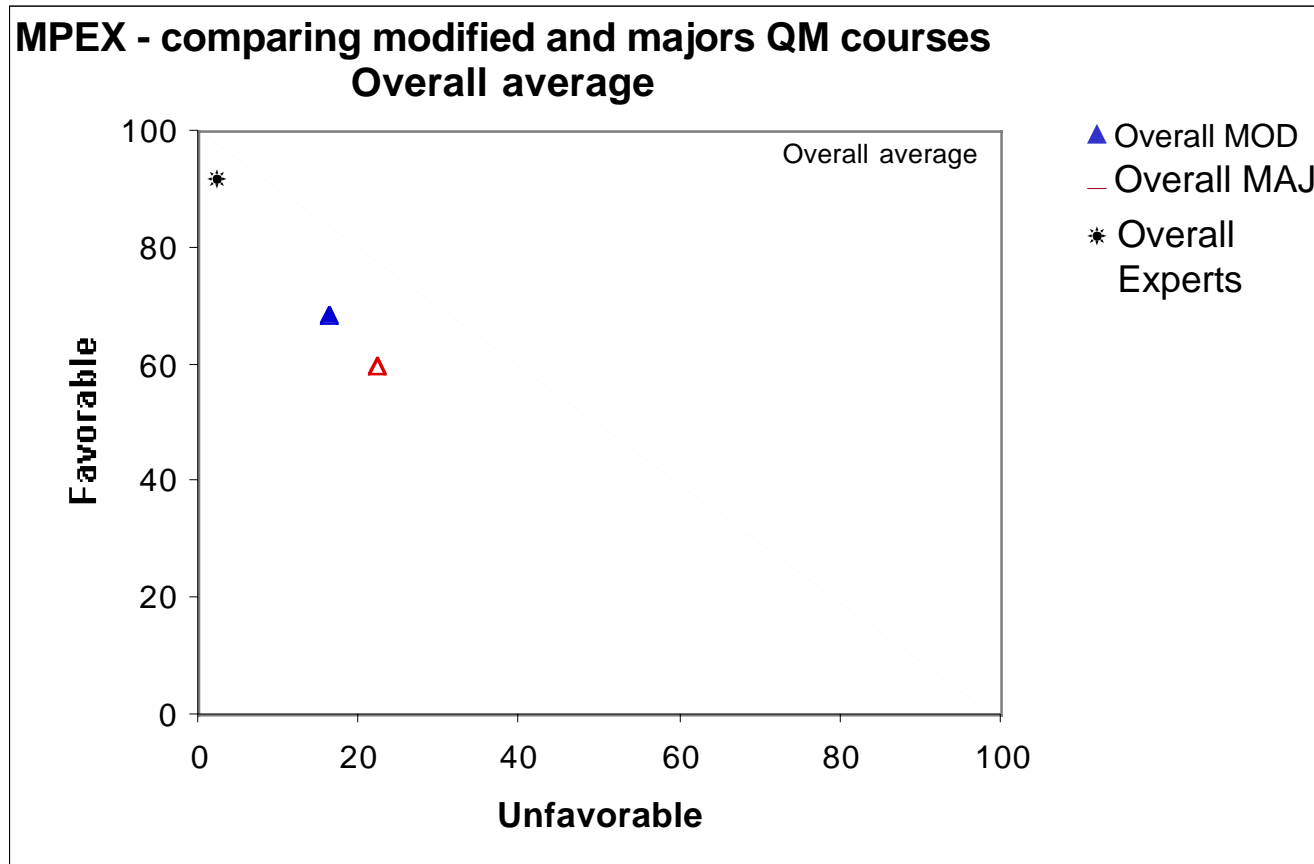


# Sample MPEX questions - Reality cluster

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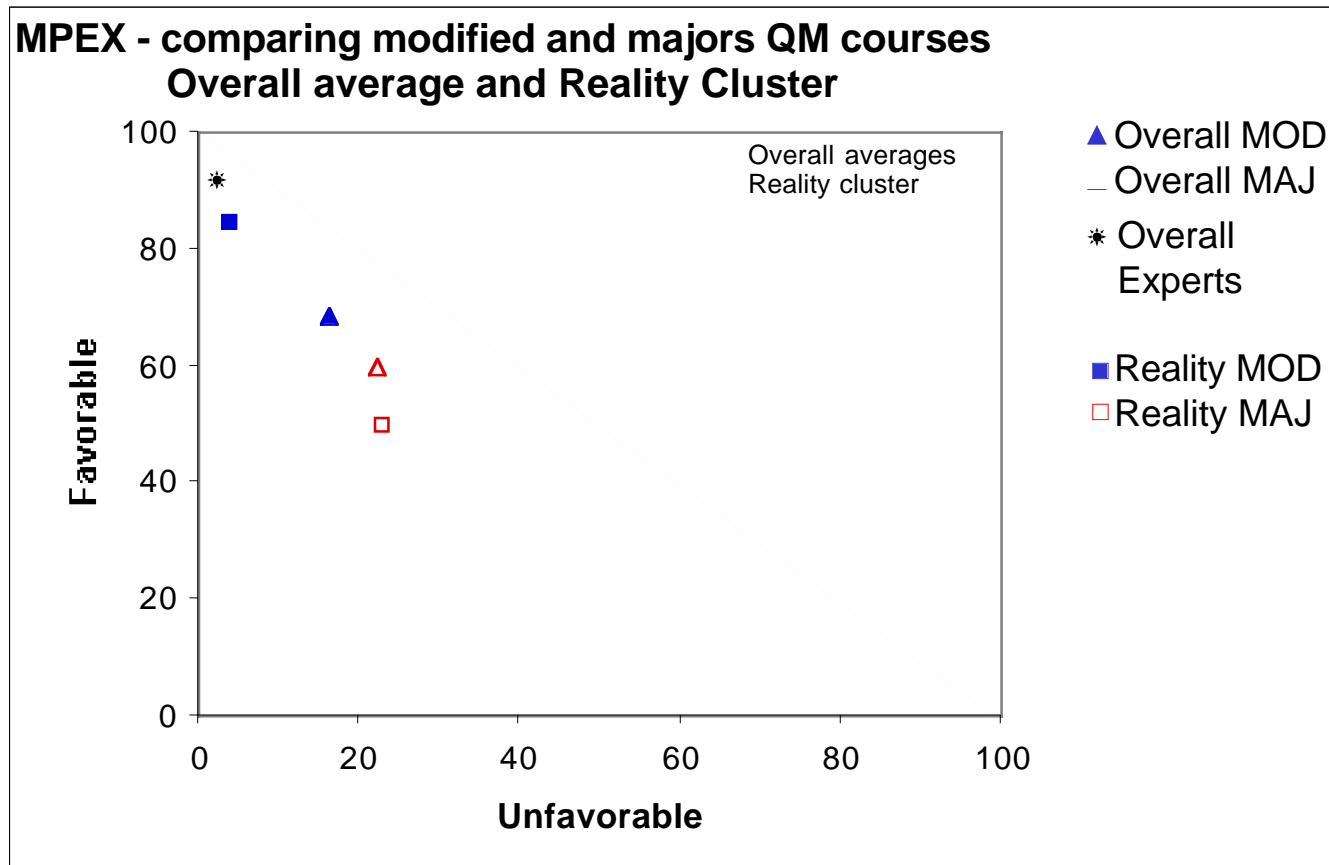
- Learning physics will make me change some of my ideas about how the physical world works.
- Physical laws have little relation to what I experience in the real world.
- To understand physics, I expect to think about my personal experiences and relate them to the topic being analyzed.
- Physics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for what I will have to do in this course.

# MPEX results, overall scores



Both groups score higher than engineers at the end of the introductory sequence

# MPEX results - reality cluster



- Modified course scores are at “expert level” (like intro sequence Workshop Physics courses)
- Majors course is in range of introductory sequence lecture/lab/recitation courses (including tutorial/GPS)

# Conclusions

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- Research-based understanding of students can help in creation of daily teaching materials.
- Research tools can help evaluate effectiveness of implementation of materials.
- Quantum mechanics can be taught so that students see a link between QM and the physical world.

URL: [www.physics.umd.edu/perg/qm/qmcourse/](http://www.physics.umd.edu/perg/qm/qmcourse/)