

American Association of Physics Teachers/ American Astronomical Society Joint Meeting

January 7-10, 2007 – Seattle, Washington
notes by Dave Van Domelen, Kansas State University

Things were a bit different this time out, since while it was theoretically a joint meeting with AAS, it was functionally an AAS meeting with bonus AAPT content. In other words, we did things the AAS way, including session names and so forth. We did get to keep our own formats, though, so contributed talks (called Oral Presentations in the program) were 8 minutes with 2 for questions again, rather than the AAS format of 5 minutes with 3 for questions. But pretty much all of the plenary sessions were for AAS, so I didn't take notes at any of them.

The workshops took place January 5-6, I didn't attend any.

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Abbreviations

There are a few concepts that came up frequently enough in the talks I attended that I gave them their own abbreviations. I've just been adding to this over the years without removing anything, so not all of these terms will appear.

ADT – Astronomy Diagnostic Test

BCI – Biology Concept Inventory

CSEM – Conceptual Survey of Electricity and Magnetism

CT – Cooperating Teacher, the person in whose classroom a student teacher works.

ECR – Elicit, Confront, Resolve. The UWash method.

FCI – Force Concepts Inventory, a common mechanics test.

FMCE – Force and Motion Concept Exam, a common mechanics test. I may sometimes type it as FCME.

GG – Gender Gap, a disparity between male and female results, usually to the detriment of the women.

IE – Interactive Engagement, one of many strategies that get students more involved in their own learning.

IRB – Institutional Review Board, the people in charge of approving research involving human subjects.

ISLE – Investigative Science Learning Environment

K-N – Where N is 6, 12, 16, 20, etc. This refers to Kindergarten through the Nth grade. K-16 means through college, K-20 means through grad school.

MBL – Microcomputer Based Labs

MPEX – Maryland Physics Expectations Survey, a test of student expectations about physics and physics courses. MPEX2 is a recent revision.

N1L, N2L, N3L – Newton's First Law, Second, Third.

PRS – Personal Response System, a means of letting students answer multiple choice questions in class using a remote control. AKA "clickers".

SPS – Society of Physics Students

TIMSS – Originally "Third International Math and Science Survey", but they changed what the acronym means in order to keep using all the logo stuff as they move on. ☺

I will sometimes add personal comments in [brackets]. I will try to withhold value judgments most of the time...if you feel the need to argue a point about a paper, please contact the author, not me (email addresses provided when possible, but the program did not include them this time). However, if you are the author and feel I have missed the point of your paper, let me know and I will attempt to remedy the situation.

Sunday, January 7

046 – Innovations in Teaching Astronomy

046.01: Survey Instrument Probing Student Understanding of the Greenhouse Effect – John M. Keller, Cal Poly San Luis Obispo, <http://www.calpoly.edu/~phys/jkeller.html>

The survey instrument in question is the GECEI, Greenhouse Effect Concept Inventory [not enough info provided to tell if it meets the strict definition of a concept inventory, but it did go through the usual open response/multiple choice with explanation/validation cycle]. It has about 20 items on energy flow, balance, etc, and is intended to take 10-15 minutes to administer. It is not, in its current form, meant to address issues of manmade climate change, merely the basics of the greenhouse effect itself.

The topics on the GECEI include types of gases, types of electromagnetic energy, energy balance, greenhouse effect mechanisms, and a little bit on the difference between global warming versus natural greenhouse effects.

There exist 22 previous surveys that Keller is aware of on the general topic, but all were either true/false or Likert scales, all were pretest-only, and most focused on global warming rather than the physics behind the greenhouse effect.

Misconceptions discovered by the GECEI included: conflation of greenhouse effect, the ozone hole and global warming; thinking the Sun mainly gives off UV light rather than IR through visible; thinking UV coming through the ozone hole specifically causes the greenhouse effect; thinking that molecules rather than energy were being trapped by the greenhouse effect; ignoring re-emission of heat from the ground and atmosphere.

Lecture tutorials on the topic were tried, and gave better gains than simply lecturing.

Future directions include a more explicit focus on global warming.

046.02: Misconceptions in Astronomy and Physics – Andy Veh, Kenai Peninsula College (Alaska), aveh@uaa.alaska.edu

Observational astronomy is tricky in Kenai Peninsula, because it's frequently cloudy, and the moon isn't even above the horizon much of the time...it's hard to teach lunar phases when people don't even see all of the phases! Diagrams, animations and in-class demos were used to try to address this.

046.03: Ranking Tasks for Assessing Conceptual and Quantitative Understanding of Non-Science Majors in Introductory Astronomy – Ed Prather, University of Arizona CAPER (Conceptual Astronomy and Physics Education Research) Team, eprather@as.arizona.edu

Using masteringastronomy.com for online tasks, students were presented with pictures or diagrams of various things, and asked to rank them according to some principle, such as size, distance from Earth, age, etc. The online interface let them move

the objects around on the screen to rank them, and the system could tell the difference between a significant difference and "almost the same".

Eight topics were studied, with the best pretest scores being around 30%. Traditional lecture raised scores to around 60% on average, and then the ranking tasks further raised scores to about 75%. About 100 students were studied, and there was no gender gap in the results.

There was a wide range of performance in the pretests, but by the end of the process, students from the lowest scoring pretest group were performing at almost exactly the level of those who had scored well on the pretest. The low-performing students catch up, but the high-performing students also improve.

Masteringastronomy.com was found to be useful for these tasks, and could scaffold up to "real" problems pretty easily. It allows for feedback, and the use of leading questions for help.

046.04: Sorting Tasks and Vocabulary-in-Context Activities for Assessing Introductory Astronomy Understanding – Timothy Slate, University of Arizona CAPER Team, tslater@as.arizona.edu

Continuation of 046.03.

Rapid and meaningful feedback is known to help learning, but large-classroom courses have difficulty with giving this feedback. Either homework is multiple choice (or other easy-to-score styles), or it's not graded and therefore seen by many students as pointless and optional.

The goal, therefore, is to get students more intellectually engaged while providing feedback and avoiding "pointless" ungraded assignments. The use of online homework helps here, especially if you can give assignments that flex more mental muscles than traditional multiple choice. The ranking tasks of 046.03 are one example, as are category sorting tasks. Using movable images as with the ranking tasks, students are asked to place the images in various categories (i.e. old vs. young). Hints are in the form of leading questions, which deduct points from the overall score only if the student gets the leading question wrong. Students are also only told how many items are mis-sorted, not which ones (kind of like a Price is Right game).

In addition to sorting tasks, there's the matter of vocabulary. Analysis shows that the Astronomy 101 course at Arizona introduces more new terms than French 101, but simply having them memorize terms isn't a Good Thing. The online feedback system lets them teach terms in a more conceptual manner. [Speaker was moving very quickly by this point, I may have missed something important.]

046.05: Visual Activities for Assessing Non-science Majors' Understanding in Intro Astronomy – Daniel Loranz, Truckee Meadows Community College, dloranz@scs.unr.edu (associated with University of Arizona CAPER)

Using the same online system as the previous two talks, these activities couple conceptually rich questions with interactive tools such as simulations, figures and photos. In addition to being used on MasteringAstronomy.com, it's available for MOODLE, LON-CAPA and other similar systems that have both branching questions and flash or JavaScript capabilities.

The tools have overlapping genres: metaphorical, mechanical and temporal. Students are given buttons, sliders and other controls to let them manipulate the systems, and they need to delve into the figures to extract information in order to answer the questions.

Mechanical figures involve adjusting variables other than time. Temporal figures show time progression of a system. Metaphorical systems are very similar to mechanical ones, but are more simplified models [I think, the talk wasn't very clear about the difference].

28 visual activities cover the full range of introductory astronomy topics, and they're currently "live" and gathering validation data.

Some preliminary results include: students tend to trust simulations too much, taking them as real (but they do find 'errors' in the simulation when it counters their expectations, even if it's not in error); students tend to avoid using the interactive figures and just guessing at answers; students get accustomed to "low cost penalties" and are willing to just use multiple guess techniques.

As a result, penalties for errors will be increased, and they will try to make it harder to avoid using the interactive visuals.

046.06: A New Chart and Teaching Materials on Cosmology from the Contemporary Physics Education Project (CPEP) – Samuel Lightner, Westminster College (PA), <http://www.cpepweb.org>

CPEP is the same group that created the Nuclear Physics Wall Chart, and an early version of the cosmology chart was field tested in The Physics Teacher back in 2003.

A number of activities have been developed as a complement to the chart (the new version of which was handed out to attendees), such as a standard candle activity, modeling of Hubble expansion, the use of a Slinky™ hung from the ceiling to show elongation of wavelengths over time, etc. An online resource with many of these activities can be found at <http://www.unverseadventure.org>

046.07: Asteroids and LSST EPO – Stephen Pompea, National Optical Astronomy Observatory, spompea@noao.edu

The LSST (Large Synoptic Survey Telescope) is capable of producing 300 DVDs' worth of **reduced** data every night, and part of their mandate is to provide this information for educational purposes. This talk in specific is looking at appropriate activities for middle-school students using LSST data.

It was decided that asteroids made for a good topic to capture student interest, but early plans to have students discover asteroids were abandoned, because automated asteroid hunters will be up and running soon, and they want a project that can be continued meaningfully for 10-15 years.

Instead, students will be given data from LSST on known asteroids, and use the data to analyze and classify them. This will also allow for more tie-ins with the earth science courses most of these students will be taking (i.e. compare Terran rocks with asteroid rocks).

The project will have both web-based and in-person activities (such as analysis of Terran rocks). It's currently in development, alpha-testing some of the interfaces with

students. The plan is to create short, one-week supplemental modules that can be plugged into the curriculum, rather than dedicated courses.

Those interested in participating, or in more info, can check out <http://www.noao.edu/education/noaoeo.html>

JPER Crackerbarrel

As things evolve in the PER field, it has been decided that JPER will be renamed and just be a general thing for PER professionals, regardless of whether they're grad students, junior faculty or tenured. Also, there will be multiple crackerbarrels at Greensboro: a general PER faculty one, a grads/postdocs one, and one focused on the needs of solo PER faculty (i.e. those who are the only PER person at their school).

Most of the rest of the crackerbarrel was taken up by discussion of two institutions that are looking to hire PER faculty.

CSU Chico is looking to build a Science Education "unit" (which may become a department later if the participants want), with six tenure track hires. They hope to get three PER hires out of the six, but this depends in part on the number and quality of PER applications submitted. <http://www.csuchico.edu> for more info.

Oregon State University's "Paradigms in Physics" program has been performing curriculum development, revising the upper division courses, and now they're looking to hire some PER faculty to help expand this into the introductory curriculum. Definitely a teaching postdoc and one tenure track position, possibly a second. The tenure track positions will be 80% teaching/20% "scholarly" (not necessarily peer reviewed publication) and a standard 50/50 job as the possible second position [I think, I may be mixing up some info]. Concerns were raised about the long term prospects of someone hired on an 80/20 track: they could end up a "second class citizen" within the department, and it might also hurt their prospects for being hired elsewhere later on. This ended up turning into a general discussion of the perils and merits of any non-traditional promotion structure.

[Left early to make it to the next session on time.]

058 – Context Rich Lab Problems

058.01: Undergraduate Labs for Biological Physics: Brownian Motion and Optical Trapping – Kelvin Chu, University of Vermont

The course under discussion is an interdisciplinary one, a "soft condensed matter physics" course for both physics majors and life sciences majors. It has helped steal a few majors out of life sciences for physics.

The course looks at "life at low Reynolds numbers", such as how bacteria can only "coast" about an angstrom in water, so all movement requires effort. Video microscopes are relatively cheap, and are used extensively in the course.

One example is examining the motion of a 1 micron silicon bead in water using ImageJ motion capture software (<http://rsb.info.nih.gov/ij>) and doing a lab on Stokes viscosity. They can see typical random walks due to Brownian motion, and then use

optical trapping to dampen this, and see the difference in ImageJ. The optical trap can then be modeled as a harmonic well.

This has been the first step in creating an entire set of biological physics experiments with an inquiry basis.

058.02: Alternatives to Traditional Labs: a Discovery Lab Based on Analogy
– Mark Liff, Philadelphia University

[This was essentially a 15-20 minute "here's a thing I did" talk badly trimmed down to 8 minutes. I took notes, but looking back I can't really figure out how the lab had anything to do with analogy or any of the "creativity research" things the speaker opened with. Rather than just copy down the rambling notes, I'm omitting this talk.]

058.03: Student Understanding Difficulties Research – Based on Conceptual and Numerical Labs – Sergio Flores, University of Juarez

A sequence of statics labs was split into four one-hour conceptual sessions with pretests and four ninety-minute "numerical" lab sessions. Each numerical session took place one week after the conceptual session on the same material. The pretests included diagrams and ranking tasks, with similar items being asked again on posttests. There was no real improvement pre/post, nor improvement over post-test performance in the traditional labs. In fact, some of the conceptual activities seem to have created new misconceptions.

058.04: Teaching Optics Topics in College Physics Laboratory – Roman Kezerashvili

[This was a rapid-fire list of optics experiments, none presented for long enough that I could take meaningful notes. Lots of PASCO microwave experiments used as analogies to visible spectrum experiments. Ended with an ad for the lab manual containing the experiments. I'm not too keen on ad talks.]

058.05: A Laboratory on Pulse Trains, Counting Statistics, and the Central Limit Theorem for Physics Students – David Pengra, University of Washington

Cosmic ray detector experiments measures pulses and the intervals between them. This nonrepeating data is good for demonstrating how statistics work with real data. [Unfortunately, the speaker zoomed through a lot of statistics too quickly for me to take notes, but the key point was that as the number of pulses being counted rose, behavior approached a nice exponential. I think. Calculus II-level math can be used by students productively with cosmic ray detectors.]

058.06: Crafting a Gauss Gun Demonstration – Matthew Blodgett, University of Wisconsin River Falls, SPS (undergrad)

The gauss gun was presented as a nicely scalable project, simple enough to be started by a freshman, but with enough inherent complexity to allow for progressive refinement through a senior project. Plans can be found at <http://www.jeffhove.com/robots> and a good gauss gun can be built using under \$100 in parts.

His early prototype fused the switch and crushed the barrel, requiring a non-sparking switch and a slightly stronger barrel (the original was a drinking straw, so no big loss when it does get crushed). The current version is built into a plastic toolbox for portability and electrical insulation. Once he works out all the kinks, he expects a muzzle velocity of about 30 m/s.

It's important to design the power supply first and then get capacitors to match it. He went the other way, and it caused lots of problems. You also want a high voltage, low capacitance capacitor...high capacitance can lead to oscillation within the barrel. A megaOhm resistor should also be placed across the capacitor to bleed off charge and avoid self-charging effects.

[He did not bring the actual apparatus, probably because of its fragility and issues with airport security.]

058.07: Using a Tube of Fire to Demonstrate Various Gas and Wave Properties – Don Cameron, University of Denver High School, dcameron@du.edu

Essentially, the apparatus was a furnace pipe section with a line of holes (1/16" diameter) drilled in it at regular intervals, sealed at both ends and connected to a propane tank. One end was a membrane. By lighting the gas coming out of the holes, a line of flames is created. Longitudinal waves sent through the gas via the membrane result in more or less gas jetting out at a given hole, so the height of the flames is an indicator of the local gas pressure. (Audience comment later: the membrane can sometimes come off, resulting in a fireball...it might be safer to build a dedicated speaker into the tube and seal it more permanently.)

Be sure to use it in a well-ventilated area to avoid gas buildup, but it also works best when the air is very calm, to avoid ripples in the flames other than those caused by the sound waves in the tube. A frequency generator can be used to create nice standing waves, or you can simply play music into the membrane.

Pedagogically, it helps both as a demonstration of longitudinal waves and to build towards a particle model of sound. It also demonstrates how the speed of sound changes in different gases, since the propane (or other flammable gas) won't have the same characteristics as air.

058.08: My Top Ten List of Labs and Demonstrations – Paul Robinson, San Mateo High School, laserpablo@aol.com

This was a series of video clips of the top ten labs and demos the speaker uses in class.

10. Flying pig hanger. One of those flapping-wing toys that flies around on the end of a string, useful for demonstrating centripetal forces, period, etc.

9. Dipping a very hot metal sphere (such as one from the classic heat expansion experiment where you fit a ball through a ring, heat it, and then it won't fit) into water shows the Leidenfrost Effect.

8. The opening scene of Goldeneye (James Bond) shows a man bungee jumping off a dam, a world record for such jumps at the time. Acceleration demo.

7. The bowling ball pendulum demonstration of conservation of energy. He related how one student once leaned into it. Ow.

6. The "pull the tablecloth off really fast and leave the dinnerware undisturbed" trick. Inertia.
5. Breaking boards with your hands. Very important to put spacers between the boards.
4. An egg toss competition, throwing the eggs and catching them in their hands. Supplemented by an Arbor Scientific video on car crashes, #P2-7960.
3. Various X-Y motion demos, such as the "monkey gun" and other ballistics.
2. Anatomy of a Home Run, starring Barry Bonds. Pointing out, among other things, that the longest distance comes from initial angles less than 45° , demonstrating that the approximations used in intro physics break down.
1. The bed of nails, complete with sledgehammer used to break a concrete block on the person who's lying on the nails.

058.09: My Most Annoying Demonstration – Joseph Mosca, Embry-Riddle Aeronautical University

Another demonstration of longitudinal waves. Take an aluminum rod, such as the type used for ring stands (1/2" diameter works well) and hit the end with a hammer to create a longitudinal wave in it. You can hold it at the nodes and not dampen the sound, as well as force higher harmonics by holding onto nodes other than the center.

What makes it annoying is that the resulting sound propagates primarily along the direction of the rod. So you can aim it at sleeping students.

063: The Future of the Core Curriculum (Panel)

063.01: The Future of the Core Curriculum in Graduate Education – Michael Thoennesen, Michigan State University (chair, labeled as 1 below). Speakers – Ken Heller, University of Minnesota (2), Laura Bodine, University of Washington (3), Michael Paessler, North Carolina State University (4). Audience comments will be prefaced by "A", my own by "Me". The Oregon State University speaker from the JPER crackerbarrel will be indicated by "O". The actual discussion isn't quite as disjoint as my notes make it look, I didn't write down all of the little segues.

Michael Paessler is an author of a report on the core curriculum, said report being the impetus for this panel discussion. The task force that created the report worked from data generated by a web survey made by APS's statistical branch.

3: University of Washington (UWash hence) has grad students take three courses at a time over three quarters their first year, then an extended core going into more area-specific courses the second year. University of Wisconsin spreads the regular core out over two years.

2: University of Minnesota (UMinn hence) has the same basic plan as UWash, but over two semesters rather than three quarters. They're trying to speed up the time to completion of a PhD without crushing the students under accelerated coursework. Also, the university charges the department more for the support of a grad student who hasn't completed the core, creating impetus to trim the core. Speaker is disturbed at how little the core seems to have changed in over forty years.

4: Is the increasing amount of time needed to get a PhD due to time spent on the core, or time spent after the core? (No one really could answer that definitively.)

1: Do we even need to change the core? Does the staleness of the core curriculum drive away potential students who find it boring?

A: There has been some change in the core, actually.

4: Agreed. The course names may have stayed the same over generations, but the content of the courses themselves has been evolving over time. (We'd come back to this theme.)

A: For instance, fluid/nonlinear dynamics material has recently become a part of the core, sometimes under its own name, other times as part of existing courses.

A: "My grad core was just undergrad courses, but harder." Is this good or bad? It can help understanding to go over the material again at a higher level of difficulty, but it can also be a boring grind. Also, going for a PhD should be about learning to do your own research, not rehashing what's already known.

A: The core does help make sure people are on the same page.

Me: I asked how many people had placement exams for their grad students, rather than self-placement or purely transcript-based placement. Only about 5-6 raised their hands. I suggested that proper placement could avoid some of the "like undergrad but harder" boredom, by making it easier to opt out of things you already get.

2: UMin just lets people opt out of core courses if they feel confident they know the material. But almost no one opts out.

A: Why have a core at all?

4: To prepare students to formulate problems from basic principles.

A: Is this theoretical or experimental preparation, though? Is the core biased towards theoretical physics students.

4: There's too much diversity in the skills needed for experimentalists to really do it justice in a core curriculum, while theoretical work has a larger body of common material.

3: UWash has upper division undergrad experimental courses in different areas, and grad students going into experimental areas are encouraged to take these.

A: Statistics skills are weak in experimentalists, they could stand to have a core course in grad stat methods (as opposed to statistical mechanics).

A: Put experimentalists in RA positions right away, don't make them be TAs.

Me: (Back to the stats thing) Error analysis is often being taken out of intro courses to make more space for conceptual material, but never really finds its way back in at higher level courses.

A: What about lab method courses?

2: "Standard courses" are inefficient anyway, transmissionist in nature. Grad school class sizes are small, we **should** be able to stick to a more interactive engagement style, since we don't have 200+ students in a class. An apprenticeship model is known to be better...do we really need core courses at all?

A: "We want to go to an apprenticeship model here." Should advisors be given freer rein? But maybe a broader education is still good.

2: The department still needs to set some standards. But those standards shouldn't just be a checklist of courses.

4: Grad school in general has an "hours" requirement you need to deal with in terms of enrollment, so an apprenticeship model would need to figure out how to deal with that.

Me: I brought up Ohio State's attempt at "Jackson by Inquiry," which some loved and others hated, and suggested that an apprenticeship program might meet similar problems of split opinions.

2: Do it all! Let some take the core, let others go for apprenticeship, tailor it to the student.

A: So few really know the whole core as professors, so doing Jackson material by apprenticeship can't work if only one or two out of the whole department understand Jackson in the first place. The core allows for more efficient use of faculty time.

2: If we're not all capable of teaching Jackson after having been through the core system ourselves, doesn't that condemn the system?

A: What consensus, if any, is there regarding what you need to master in order to be considered a physicist?

1: We may not need to **master** it all, but it's valuable to be at least familiar with the whole core.

A: If only a few apprentices learn topic X, who will be able to teach it N years down the road? Also, one has to consider the difference in qualifications between "physicist" and "physics faculty".

O: The core obscures what we do, and has been carefully designed to do just that. Standard courses are **names** rather than **content**. Maybe we should rename the courses to be more descriptive of what's actually taught in them? De-monolithize the courses, look at the topics rather than courses as blocks. Then toss out topics you don't consider important and bring in new ones, mix and match to make new courses.

A: The core degenerates into mathematical manipulation exercises in many cases. We need more about following extended arguments and logic. The actual math used by most physicists in Real Life is actually pretty low-level compared to stuff like Jackson.

A: (grad student speaker) Undergraduate research apprenticeship was really valuable, but the collaborative problem solving sessions in grad school are equally so. Having a common problem set generated by the core makes it a lot easier to collaborate on problem solving.

2: Having fewer than "all 30" grad students in the core can still result in core-like clumps large enough to allow for such collaborations. On the other hand, the monastic cell types, the lone wolves, might benefit from a more self-paced curriculum. And if Oregon State can do this sort of thing in upper division undergrad classes, why not in grad schools?

A: Boulder now has a more modular core, with chunks that can be added or removed, and it seems to work.

A: The core comes from trying to set up a systematic approach to knowledge, based on "simpler times" 50+ years ago when it was theoretically possible to be less specialized in physics. Does the modern explosion of knowledge drive a move to eliminate the core so that people can choose a specialty sooner in their careers?

1: Perhaps it would be better to expand the number of grad degrees, creating multiple cores? For instance, a Biophysics PhD, rather than just Physics with a specialty in Biophysics.

A: Inertia is a powerful opposing force. Any change will mean a lot of work.

A: The system "works" now in that lots of original work is still being done.

1: How long do we have to wait to see if a new system also works, though? What are the criteria for "works," and how do we deal with the possibility of a weak start on a program?

2: How do we know **anything** works? We seem to have a cargo cult mentality of empty rituals that correlate with success well enough that we keep it up, without considering whether there's any causation. The "lots of original work" success may be chance, may even be despite the system rather than because of it.

O: Student responses to interviews can tell us if it's working. For instance, one student interviewed early in a reformed course showed resistance to anything other than the standard transmissionist model, but after a few weeks was singing a different tune, saying that the new way really worked for them.

3: The burden is on the student to get more out of school, in the end. You can always seek out apprenticeship opportunities even from within the core curriculum structure.

O: Unfortunately, these are "high energy state" learning styles, and many who would benefit from apprenticeships will be too lazy to seek them out. They need to be forced out of the nest.

3: But having structure is still a useful support.

A: The standard core leaves many totally unprepared for "work on your own" research.

3: Yes, students ask "When is it due?" and the professor replies, "When do you plan to get it done?"

4: There's also a pervasive attitude that if a student fails to learn, "shame on the professor." This seems to be getting increasingly prevalent, with a shift of the responsibility for learning from student to teacher. (changing topic) Comparing success in the Oregon model is very hard...how do you do a control group? Other universities are sufficiently different that they can't act as controls, and even if you do an internal control track, self-selection for the tracks is a problem unless you can hide the differences or take away student choice (which raises practical and ethical issues).

2: People come to grad school because of interest in cutting-edge, but then get hit by a year or more of the same old stuff. Some get bored and leave. About half evaporate into other departments, drop out, etc, and they leave before they really get the chance to **be** physicists. **Does the core bore?**

1: Grad schools are not limited by the need to service Engineering departments, so it's not like they have to stick to the core.

A: Is there a mismatch between incoming students and the core?

1: Do we check core knowledge in our hires of postdocs and other fresh PhDs beyond checking transcripts? And if not, would dropping the core still hurt the hireability of PhDs because they just lack the lines on their transcript?

2: We don't really seem to care about actual core knowledge on the part of postdocs. Train 'em in what they need, hire 'em for what they did in their thesis.

4: Attrition may not be all bad. Admission itself is bound to be imperfect, so attrition will happen simply because people not suited to being physicists will get in.

Me: I brought up an anecdote from grad school. Fresh out of qualifying exams, I got put on doing theoretical calculations for my AMO group, because everyone else had forgotten how and it was fresh in my memory.

A: Well, the others presumably could have relearned if they had to.

2: Faculty treat grad students as valuable resources, and won't blow off teaching them by just going through the motions. They may not **look** like it, but they care.

A: What about fear of change?

2: Change for its own sake isn't good. You need to know that the change is for a reason.

4: The core changes anyway over time. We need to control this change and direct it in a positive manner.

A: We need to consider a supplemental core.

[I had to leave at this point, but presumably the discussion continued.]

Apparatus Committee Meeting

The Advanced Lab Initiative taskforce reported to the board. Things are moving, if slower than they'd like. The Advanced Labs listserver is up and running, and working out the kinks.

There will be an Advanced Lab invited session at Greensboro, as well as posters.

An Advanced Labs conference is in the works, something like the PERC, to be attached to the beginning or end of a national meeting.

An award for exemplary work in advanced labs has been proposed, but the wheels on that sort of thing turn very slowly.

Greensboro will be a tricky meeting for Apparatus, since there will be no dedicated physics equipment room available (not only is the main conference at a hotel miles from campus, but the campus itself lacks a dedicated physics equipment room). Anyone planning to use or demonstrate apparatus will need to plan ahead very meticulously.

The AAPT.org servers will be hosting the committee webpages. A suggestion was made to add a wiki editable by committee members to make updating simpler.

Monday, January 8

118: Nanoscale Physics in the Classroom (mixed)

118.01: National Center for Learning and Teaching (NCLT) in Nanoscale Science and Engineering – Nicholas Giordano, Purdue (invited), <http://www.nclt.us>

The NCLT is a multi-institution NSF-sponsored project looking to introduce nanoscience to the K-16 curriculum, mainly junior high through college. It looks to do both teacher prep and research into curriculum issues.

In summer 2006, they organized a "big ideas" workshop to figure out the key concepts to teach, which was broken into four research work circles: scanning probe,

self-assembly, learning technologies, concept inventory. The first two groups are not topic-based despite their names, but were rather chosen for evocation of their roles. Scanning Probe group looked at trying to figure out student interests and motivations, while Self-Assembly investigated creation of activities.

The "big ideas" generated by the workshop included size/scale, the particulate nature of matter, how forces scale differently, how properties change with scale (i.e. melting point and even color depend on particle size at nanoscales), self-assembly, atom-by-atom nanotools, the social impact of nanoscience (and what problems it can solve), and models to help with visualization (representing the invisible).

The Scanning Probe work circle, since renamed NanoSlam, has decided to use the scanning probe microscope as a topic for teaching, but do students really care about it? They also seek to figure out what students know, and in what order they learn.

For instance, there are several conceptions of size and scale. Order by groups, order by multiples (i.e. "N times bigger"), order by size, and absolute size. Both that order and the order in which the first two are swapped come up commonly, although the second one is the most common trajectory.

The Self-Assembly group develops interactive activities such as "DNA origami", in which DNA strands are designed to self-assemble into "interesting" shapes such as smiley faces (of which actual probe images exist).

The Learning Tech circle looks into visual representations, things like the output images from scanning probe microscopes. They ask questions such as, "What do students really see when they look at these images?" A simulation can come very close to reality, given how abstracted real probe images are in the first place.

The Concept Inventory circle wants to create an instrument that will work for all students from junior high through college. Also, while there's a lot of facts to absorb, they want the instrument to clearly distinguish between mere fact acquisition and actual conceptual understanding. The vocabulary must be acquired in order for the student to sensibly answer the conceptual questions, but the vocabulary on its own should not be enough.

Professional development workshops are underway to test these materials with instructors. [Details glossed over as time was running out.]

The NCLT is also a model for future attempts to bring interdisciplinary materials into K-16 education. They're currently 2 years into a 5 year mission [to boldly go where no...wait, never mind]. They recognize the need for teams, since no one person can really know enough about this material.

118.02: Resource Materials for Nanoscale Science and Technology Education

– George Lisensky, Beloit College (invited)

Opened with a group activity. Take two flexible "refrigerator" magnets and drag one across the other. In one orientation, you notice only friction. In another, though, you may get a sort of rippling effect, as the striped magnetic domains line up their poles. This simulates how scanning probe microscopy works. You feel the force rather than seeing the domains.

Another simulation of scanning probe microscopy involves a pingpong ball on the end of a stick, run across "eggcrate" foam. If the ball is the right size, you can feel the

changes in the surface. If the ball is too large, you don't feel much detail. So your probe needs to not be large compared to the size of the details you're trying to detect.

Other scaffolding activities (such as using a mirror on a cantilever to deflect a laser beam and show how tiny movements can be magnified) are then used to build up to the way the atomic force probe microscope works.

One area of relevance for nanoscale physics is the manufacture of computer chips. With layers on hard drives now being as small as three atoms thick and details on silicon chips being as small as 65 nanometers, we're about to run into a limit on "Moore's Law" (that computer speed and power double about every 18 months). If we're going to squeeze out every last bit of possible processing power, it's important to have a really good understanding of the nanoscale.

<http://www.mrsec.wisc.edu/nano> is the webpage for Exploring the Nanoworld. It has an online lab manual with activities designed for various levels, from basic through advanced labs. One such activity is using a surfactant and magnetite shavings to create ferrofluid. [The next several paragraphs outline other things on the webpage.]

The properties of materials that are normally considered intrinsic actually change at different scales [as mentioned in the previous talk]. Gold is no longer gold-colored at tiny particle sizes, turning a variety of colors (including red) at smaller scales. Melting point also changes with smaller particle size. CdSe nanoparticles change color through the entire visible spectrum at particle sizes ranging from 2nm to 12nm, and they can be grown in a solution to show this change over time (larger particles mean longer wavelengths).

Alumina nanofilters can be used to grow nickel nanowires, which when placed in solution create a way to see magnetic fields. [Like iron filings in suspension, but much finer-grained and niftier-looking.]

A "TiO₂ Raspberry Solar Cell" is another good apparatus using nanoscience, and it can be used in an interdisciplinary context.

A scaffolding activity can be done using patterns of dots printed on transparency film. Shining a laser through the dots creates diffraction patterns, which spread out as the dots get closer together. Eventually you can get a screen pattern so small the naked eye has trouble resolving it, but the diffraction pattern still lets you know how far apart the dots are. This can be used to explain diffraction of DNA.

Butterfly wings are a naturally occurring nanostructure, creating their colors solely through interference and having no dyes at all.

Liquid crystals work similarly to butterfly wings, with coiled molecules allowing colors through based on the tier-to-tier separation of the coils. Heating them forces the molecules farther apart, which actually makes the coils tighter (the tips of the molecules spread out, so the angle between adjacent crystal "rods" is greater and you need fewer rods to get a full circle). This is how mood rings work, with warmth tightening the coils and making the crystals go from red through blue.

LEDs and band gap theory can also be covered, with an LED strip (various colors on a board) showing how the different colors require different amounts of energy. The higher energy colors fade faster.

[Cut off for time reasons.]

118.03: Small Talk: Conversations About Nanotechnology Through Podcasts

– Stephanie Chasteen, Exploratorium, stephaniec@exploratorium.edu and <http://www.nisenet.org> (National Informal Science Education Network – NISENet)

NISENet is looking to find new ways to inform the public, and have seized upon podcasting as one way.

It's hard to talk about nanoscale stuff. Just the fact that it **is** small is, well, boring. It's more interesting to talk about what it **does**.

The topic is conceptually difficult and unfamiliar, so they try to find some more commonplace examples, such as soap films. Also, because the topic is diverse and rapidly changing, it's important to bring in scientists doing work in the field.

They also want to address societal implications of nanotech.

SmallTalk is a series of 25 minute podcasts available either on iTunes or at <http://www.nisenet.org/podcasts>. It consists of interviews with scientists in the field, an essay (modeled after NPR's "This I Believe") and a news quiz (modeled after "Wait, Wait, Don't Tell Me").

Other useful addresses: smalltalk@exploratorium.edu, <http://exo.net/~drsteph>, <http://qt.exploratorium.edu/nise-resources>.

118.04: Nanoscale Physics Inquiry Activities – Jill Johnson, Exploratorium/NISENet. <http://www.exo.net/~jillj>

"Stretch a millimeter on a meter stick to a full meter and make new 1/1000th marks. These are micrometers. Now stretch one of these micrometers to the length of a meter and make new 1/1000th marks. These are nanometers." Alternately, to get to a nanometer, cut a meter in half 30 times. Students quickly find that after about ten cuts it gets kinda hard.

NEO is Nano Education and Outreach, a professional development program for graduate students and practicing researchers, aimed at helping them learn how to teach the public about their nanoscience work. There are free workshops (the next one is May 21-25, 2007) covered by NISE. This can help an NSF grant-funded research satisfy the "broad impact" portion of their proposal.

Some of the things covered in the workshop include:

- Scale-dependence activities, such as "skewers versus garden poles". Given bamboo skewers and bamboo poles, students build similar structures, then notice how the larger one is less rigid. Rigidity is affected by square-cube relations.

- Rolling post-it notes into "nanotubes" to show how structure matters too, and how low mass can still give high strength.

- Surface tension demo with wires. A heavy gauge wire will sink, while light gauge wires can be made to float.

- Surface area to volume ratio activity, cutting a cube of clay. The more cuts you make, the more surface area you get without changing the total volume.

- The dependence of reaction speed on surface area. Take two effervescent tablets. Crush one into powder. Drop each into a film canister partly filled with water and quickly seal. The powdered one will pop its top almost immediately, while the intact tablet will take significantly longer to build up enough gas pressure to pop open the canister.

135: Student Difficulties with Mathematics in Upper-Division Physics (invited)

135.01: Easing the Transition to Upper-division Physics – Corinne Manogue, Oregon State University. <http://www.physics.oregonstate.edu/paradigms>

[Note: this was an interactive talk, and I got recruited for a few demos, so my notes are a little gappy.]

Oregon State has been working on the "Paradigms in Physics" curriculum for its upper division courses [mentioned in the notes of a few previous sessions]. The physics major starts in the junior year at OrSU, due in part to the large number of transfers from 2-year institutions. They've redesigned the courses offered each quarter, and renamed them to be more descriptive of the content (i.e. "Oscillations" and "Energy & Entropy" are course names) while making the courses themselves more IE-oriented.

A number of problems students have coming into the major include the usual electric force/field/potential confusions, difficulty with spherical coordinates [Math department classes use what I consider the more sensible ϕ for angle down from the vertical and θ for what would be θ in polar/cylindrical coordinates, but for some reason physics classes swap them. Also, math classes don't even cover the idea of unit vectors for non-rectilinear coordinates.], etc. Students are given whiteboards and asked to commit to answers during classroom discussions, which helps determine where they need help.

Vocabulary issues were also found to be confusing. For instance, when we talk about linear charge density, we mean the density per linear meter of charge. But when we talk about linear current density, we mean the charge per square meter of a linear current. And don't get her started on magnetostatics being the study of the effects of **moving** charges.

Rapidly covered, disconnected topics (such as those chosen as examples in this talk) can be frustrating, especially if the concepts are either new, or the audience is rusty with them [i.e. how many of you can work out the spherical coordinate unit vectors right this second without looking it up?]. To students who haven't built a strong internal framework for physics yet, it's all disconnected. Also, if you change frames, it can result in student attitude problems. It can help to make it clear before covering any topics that you're going to step outside of the traditional "learn by listening to lecture" frame.

There's also an issue of a mismatch in expectations between what the student thinks will happen in class and what the instructor would like to happen. So make sure that the students are aware of your expectations and what frame you're in. Do something out of the ordinary as a metaphorical "two-by-four to get their attention" before you start on the material, such as jumping up on the table to talk. Assuming it can hold your weight, of course.

Stringing together too many unfamiliar concepts and terms can also cause parsing problems, where students not only don't know what the meaning of the words is, they can't figure out the grammar of the entire sentence. You should help students learn to chunk things grammatically, and build to full conceptual "sentences" of concepts.

One chunk that they have problems with is the idea that the same thing can be a constant in one context and a variable in another context. You need to ease them into the idea of that contextual shift. Students hate the uncertainty at first, but learn to like it.

135.02: Investigating Student Connections Between Mathematics and Thermal Physics- John Thompson, University of Maine

Research question: what difficulties do upper level students have with thermal physics, and to what extent are they the same as in introductory classes?

A junior/senior level classical thermodynamics class was investigated. The physics preparation of the average student was "minimal", but all of them had been through at least Calculus III, if not farther in their math coursework. Several specific issues were considered.

Issue 1: P-V diagrams and integrals. Presented with multiple non-closed paths on a P-V graph between the same two points, students were asked to compare how various quantities differed based on which path was taken. From a quarter to a third of the students thought that work equaled the change in internal energy, and was path-independent. Work, heat and internal energy tended to be conflated a lot.

Could the underlying math also be a factor, not just the misconception that work is a state process? Students were given a purely mathematical integration problem that was equivalent to the P-V diagram, but without the physics context, and only using variables common to calculus class. The error rate was pretty much the same as in the physics problem, with the most common mistake being to assume that the integral of $f(x)$ from a to b was " $f(b) - f(a)$ " independent of path. However, the people with the errors were not always the same: some just erred in the physics problem, some just on the math version, and some on both.

Issue 2: Partial derivatives and the Maxwell Relations in thermodynamics (i.e. $dU = TdS - PdV + \mu dN$, where P is the partial derivative of $-U$ with respect to V). For the most part, students could handle the first partial derivatives just fine. But when they went to the second derivative, especially mixed derivatives like $\partial^2 U / \partial V \partial S$, problems arose, in two main varieties.

Firstly, there was the "calc 1" problem, in which students made procedural errors like incorrect use of the chain rule and product rule, or treating the wrong things as constants. Then there were the "calc 3" problems. The first of which was that all mixed partial derivatives were zero, since in the first partial you make the other variables "constant", so there's no longer anything to differentiate with respect to (fixed versus constant as an issue). The other was simply notational, not seeing $\partial^2 \beta / \partial T \partial P$ as the same as $\partial / \partial T (\partial \beta / \partial P)$. The first problem of confusing "fixed with respect to differentiation" with "constant" seems to be pretty persistent. Note that students didn't really have a problem with the order of differentiation (Clairaut's Theorem states that for well-behaved functions you can do it in either order, which lets the Maxwell Relations work).

Students did not, however, say that the 2nd partial derivatives in the Maxwell Relations were identically zero, as they did with the ones for β ...why? One possibility is that all of the quantities in the Maxwell Relations are defined earlier independently of their nature as partial derivatives...entropy, pressure, enthalpy and so forth are all known to the students before this class, if not necessarily known well. Whereas a quantity that is first seen as a first partial derivative will trigger the constant/fixed issue.

It should be possible to write a curriculum that addresses these problems, and one is under development. Among other things, they use geometric representations of second

order partial derivatives as changes of slopes, to avoid the fixed/constant issue entirely, and this seems to help.

135.03: Students' Construction of Understanding of Abstract Vector Spaces – Thomas Bing, University of Maryland

We often try to use common underlying mathematical structure to tie concepts together, such as comparing electron spin to angular momentum. Whether we call them this or not, the tools we use are often vector spaces. Working with eigenvectors is a common upper division vector space, for instance.

Being able to see a stable idea of a generic vector space, or at least having the expectation that there will **be** one, is expert-like, and a good endpoint to try to get students to in a course. But how do students reach this goal?

A generic vector space includes the following ideas: vectors, building from a basis set, and projection of one thing onto another. Generic vector spaces may not match a formal definition of vector spaces, they're more of a student mindset.

"Generic space" is like schema theory, or classical transfer. It's often treated as binary (yes/no), you either have one or you don't. But Bing's work shows gradations in stability and expectations.

Students initially understand mathematical concepts as **processes** before they get encapsulated as self-contained **objects**. [Acquisition of the objects is the binary style, ignoring the value of the intermediate process view. I think.]

The subjects of this study were enrolled in a sophomore/junior Math Methods course, with vector spaces explicitly emphasized in the class. Different students were seen to operate at different levels of generic space use: fully generic, partially non-generic, and almost totally non-generic.

A less-generic vector space approach requires an appeal to a specific example for support, such as comparing to the Cartesian vector space when looking at a Fourier-style function space. Common terminology will cue different specifics in the examples. A largely non-generic approach may briefly glimpse the idea of a generic space, but only as a pretext to justify comparing two specific examples. They're processes to be used rather than objects.

A fully generic use tends to be dominated by structural concerns and identity (i.e. this **is** that) rather than simile (this is **like** that). Generic use shares more common terms, has larger chunking sizes, and arguments are justified by the generic categorization of the situation.

Semi-generic approaches mix structure and process. Non-generic approaches use the process of one example and just change the labels to fit the new process, making use of simile and small chunk sizes.

Context and frame can affect the stability of generic frame use. Students who were fully generic in one context might be fully non-generic in another.

Students who are generally good at thinking in generic terms are better able to take advantage of instructor analogies. On the other hand, if the instructor understands how students can operate in non-generic terms, it can help in tailoring instruction.

In the sample course, students were explicitly taught about generic spaces, and many still were non-generic.

145: Students' Use of Mathematics in Physics Contexts

145.01: Do We Need Remedial College Math Courses? – Anne Hughes, University of the District of Columbia (Daryao Khatri presenting).

At UDC, 80-85% of students require one or both of two remedial math courses, adding a full year to their college stay (Math 005 and Math 015). Each class is 3 credit hours, and those who complete the sequence are often still insufficiently prepared to continue with 100-level math courses.

In an attempt to find a way around this, they tried an intensive six-week program before the start of the college term. All students enrolled in this class had been accepted at UDC and had been required initially to take both remedial courses. The course met for four hours a day, with three hours of lecture and one "homework" session that students had to complete before they could leave for the day.

Of the 12 students who participated, 3 were able to test out of both remedial courses and 4 were able to test out of Math 005. Two female students in the group became physics majors.

Next summer, they'd like to offer this as a regular summer course open to any incoming student.

145.02: Equations in Science: Are They Hindering the Development of Reasoning Skills? – Suzanne White Brahmia, Rutgers

Looking at 8th and 9th grade physical science courses in the 1930s, Louis Benezet found that the early introduction of rote mathematical methods tended to dull reasoning skills (<http://www.inference.phy.cam.ac.uk/sanjoy/benezet> for more). He felt it was better for grad school students to focus on reasoning skills, and leave formal mathematics until at least 8th grade.

The Physics First movement hopes to better prepare students for science content and math applications by introducing physics content in 9th grade. But, based on Benezet's findings, it really should focus on helping students develop reasoning skills.

The starting topics in most physics classes tend to look like a bunch of disconnected and memorizable facts, and the "aids" in most traditional textbooks are focused on helping with memorization while actually impeding the development of reasoning skills. They provide students with algorithms that allow the students to get the desired answers without understanding the material.

When asked to go outside their toolbox of algorithms, most students are utterly lost.

Some examples of what we should be doing rather than giving them algorithms: teach what integers really are, teach the various meanings of zero (the empty set, the origin of coordinate systems, a balance point between positive and negative).

145.03: Connecting Math and Motion: A Covariational Approach – Robert Culbertson, University of Arizona

MSP is the Math/Science Partnership, which exists to train in-service science teachers at the Junior High School and High School levels. It uses a five course sequence on various topics, and the second course is CPCM, Connecting Physics, Chemistry and Math.

Covariational Reasoning (CR) is the ability to correlate changes in two connected variables, correlations that need not be linear. For instance, comparing position and velocity.

Teaching CR explicitly has been successful in improving scores on the TUG-K and related instruments. The curriculum includes the use of multiple representations, such as linked graphs showing pairs from among several relevant variables, with animations that show how changing one thing changes the others. Improved qualitative and quantitative understanding has been found.

145.04: Principles of Covariation in the Introductory Physics Classroom – Adam Thompson, Arizona State (presented by Culbertson, continuation of 145.03).

An example of a CR task is the comparison of volume to water level in bottles of differing shapes. Regardless of shape, raising one will raise the other, but the details are strongly dependent on the shape.

CR leads directly to "rate of change" concepts, which are fundamental to physics.

A research question was asked, "Is CR in community college introductory physics students correlated to course performance?" The students in question were taking an algebra-based mechanics course. Only students who passed the course were considered, since failure/dropping out often happens for reasons unrelated to student ability (financial, medical, motivational, etc). CR was evaluated several times during the term, with students given data in tabular or graphical form and asked to draw conclusions from it.

The evaluations were based on the quality of the responses, and were graphed against bins of student course grades (A/B/C). The correlation was fairly low, possibly due to a ceiling effect in the CR evaluations (a lot of students got the maximum possible score), but it was positive.

145.05: Teaching Kinematics as a Way to Understand Calculus and Graphs – Genaro Zavala, Tecnológico de Monterrey

The kinematics content of a remedial physics course was used as the basis of this study. Significant figures were introduced as a way to indicate measurement precision, and students were asked to calculate average velocity for various intervals, compared to the instantaneous velocity found via $\Delta x/\Delta t$ limits, both graphically and calculationally (with arbitrarily small Δt values). Then calculus was used to compare to the results already obtained, and found that within the limits of the significant figures provided, the calculus and non-calculus methods were essentially equal.

Our limits of precision tell us when an approximation is good enough.

145.06: Student Understanding of Probability and Introductory Statistics in Upper-Division Courses in Thermal Physics – Michael Loverude, CSU Fullerton, mloverude@fullerton.edu

Thermal Physics (Phys310) meets twice a week for 75 minute lectures. About a sixth of the students have taken college level statistics/probability courses prior to enrolling in Phys310, and preparation/backgrounds vary widely.

The 2nd Law of Thermodynamics arises from a large-N statistical ensemble, so they want to make sure students understand what that really means. They start with coin

flip problems (i.e. "which of these results is more likely? HHHTH or HTHTH?") which trip up many students. Students tend to confuse microstates (permutations) with macrostates (combinations). For instance, in six coin flips, there are 7 macrostates: all heads, one tail and five heads, etc. But there are 64 (2^6) microstates. A result of one tail and five heads is actually six times more likely than a result of all heads, but students treat the two macrostates as each having a one in seven chance of occurring.

Additionally, intuition about large-N statistics is very bad. When asked which was more likely, 1 head out of 6 flips or 100 heads out of 600 flips, many students said they were equally likely. When, in fact, the one out of six case is something like fifty orders of magnitude more likely than 100 out of 600.

It seems that many micro vs. macro problems are hardwired into the way our brains work.

[Aside: one thing I've run into in my own research on student views of randomness is that many are taught in math classes that if something is random, all outcomes must be equally likely (conflating "random" with "fair"). This would tend to reinforce micro/macro confusion, if they think of the combinations as the random results, rather than the permutations.]

145.07: Student Solutions to First Order Differential Equations in Intermediate Mechanics – Michael Wittman, University of Maine, wittmann@umit.main.edu (presenting for Katrina Black, UMaine grad student)

Mathematical equations carry more meaning when placed in a physics context. How do students use their math knowledge when in a physics context?

Sample problem: find velocity as a function of height for a beach ball thrown downward from the top of a building, where the initial velocity exceeds terminal velocity.

Students tended to use two basic methods in their solutions. Both methods would apply N2L, choose the variables, separate the variables, and then integrate.

The "+c" method would perform an indefinite integral that would result in an answer containing an arbitrary "+c", and then the students would apply boundary conditions to determine the value of c. They called this the "normal" method, and is the way they mostly do things in math classes.

The "limits" method would perform a definite integral with limits of integration based on the initial conditions. This is the way physicists tend to solve integrals, and it allows us to see the functional properties of the limits of integration better.

A consistency plot was created from the data. The horizontal axis was the method used, with "limits" being at the origin, "+c" to the extreme right, and hybrid methods in the middle. The vertical axis measured the correctness of the solutions (fully correct at the origin, fully wrong in the positive y direction). No one who used a pure "+c" method got the problem completely correct. Over time, student solutions moved around on the graph (bad changes being towards the upper right, good changes towards the origin), but there was no real consistency. Hybrid models did not seem to help move students towards the correct model.

When interviewed, students considered "+c" to be normal, but tended to follow the lead of the instructor and used limits even though they didn't have faith in it.

145.08: Using Mathematics to Inform Conceptual Reasoning About Quantum Tunneling – Jeffrey Morgan, University of Northern Iowa (work done with Wittmann)

Consider a particle approaching a finite square barrier from the left, moving right. The barrier has a height of V_0 in the range $0 < x < L$, and energy conservation principles are used to solve the problem. You get a sine wave on either side of the barrier, and an exponential decay inside the barrier. No energy is lost, but $P(\text{left}) > P(\text{right})$.

When asked conceptual questions about this problem, students tended to be stumped. But it was possible that they could at least solve the quantitative part of the problem, and some proposed that after solving the quantitative problem the students would be in a better mindset to properly answer the qualitative problems.

Switching to an asymmetrical barrier (potential zero on the left of the finite barrier, but negative and finite to the right) in order to avoid issues with excessive student familiarity with the problem (smallish department, and most of the students had been interviewed as part of the previous study), students were first asked to solve the problem mathematically, then they were asked conceptual questions.

Students had trouble linking their correct mathematical solutions to correct conceptual results. They could do the math, but didn't know what it meant. Mathematical priming didn't really help...writing a solution is not the same as understanding it.

Laboratories Committee Notes

Everyone was encouraged to join tap-1, accessible via <http://www.aapt.org>.

A few more details were raised about the Greensboro meeting. The conference center used for the main conference shares its parking lot with a mall, so there's free parking for those who want to stay somewhere other than the conference center hotel (not to mention a decent variety of nearby food options, so those staying in the dorms a few miles away should probably skip the meal plan, or only get breakfasts).

The mission statement was edited, and the changes voted on.

Looking ahead to Baltimore, several sessions were proposed and considered. One would be a session on scientific reasoning and discourse. Covariational reasoning and graphical analysis were brought up as possible parts of this session. Another proposal was for a "Labs for Physics First" session.

A workshop on medical technology labs was proposed, assuming that the meeting theme would indeed be medical tech, and the issue of human subjects approval was brought up. Just hooking an EEG to a student requires IRB approval.

Cochlear implant researcher Dewey Lawson was suggested as a possible plenary session speaker. He works with cochlear implant recipients to compare the difference between normal hearing and implant-assisted hearing (most subjects have one normal ear and one assisted).

In 1993 there was a Labs focus at the AAPT meeting, with three tracks: high school, introductory labs, advanced labs. These focus groups resulted in the Labs committee being formed, as well as an official AAPT statement on introductory labs. There was a big professional development impact on participants, and it helped get the early Microcomputer Based Labs spread around. A large resource document also came

out of this focus. It was suggested that it may be time to get a new Labs focus group together.

Tuesday, January 9

188: PER – Student Understanding and Student Reasoning

188.01: Techniques and Tools for Teaching the Photoelectric Effect – S.B. McKagan, University of Colorado (PhET group)

The Photoelectric Effect (PE) is very important to modern physics, but it's treated as "straightforward" by many instructors...and it isn't. (See, for instance, AJP **64**, 1370 (1996)). Students have many problems with it.

PE Tutor was made as an add-on to the traditional curriculum, and has had some success. But can things be made even better by designing a curriculum around PE? PE Sim (<http://phet.colorado.edu/web-pages/index.html>) has been created as part of such a curriculum, and is used in three lectures and two hours of homework. The lecture component uses "clicker questions", asking students to make predictions before the simulation progresses. The homework included essay questions.

One consequence of this is that students started asking really hard questions! This included, but was not limited to, poking at the simplifications inherent in the simulation. PE Sim did successfully help students above and beyond the aid rendered by PE Tutor.

<http://jilawww.colorado.edu/~mckegan/2130archive> has more materials, log in with username admin and password bohr.

188.02: Examining Student Understanding of Quantum Wavefunctions-
Homerya Sadaghiani, University of Washington

This work was done using classes at both Ohio State and University of Washington over the course of several years. All data was taken from post-lecture students, and the results have been remarkably consistent across populations, so all data will be presented as a single group.

Students have difficulty distinguishing between general wavefunctions and eigenstates. In other words, for a generic $\Psi(x,t)$, they think the time evolution is given by $\Psi(x)e^{-iEt/\hbar}$ with energy E even if it's not an eigenstate and $H\Psi \neq E\Psi$.

There's also difficulties with multiple representations of wavefunctions. While 75% could correctly answer a question using a graphical representation of a wavefunction, only 40% could answer it correctly if the problem was stated as an equation. 30% were correct in both representations. There seems to be poor association between representations.

Students failed to distinguish between a decaying $e^{\pm cx}$ and the oscillating $e^{\pm icx}$. Material is being developed to address these concerns.

188.03: Pedagogical Landscape in Upper-Level Thermal Physics – David Meltzer, University of Washington

[Unfortunately, this was a 25 minute invited talk crammed into 8 minutes, and I was not able to take meaningful notes.]

188.04: "Is Entropy Conserved?" Student Understanding of Entropy in Introductory Physics – Warren Christensen, Iowa State

[This looks at one aspect of the material covered in 188.03.]

Students who were about to cover the 2nd Law of Thermodynamics and Entropy in an introductory course were given a pretest. The pretest tried to strip out any technical vocabulary that they might not be expected to know pre-instruction, and had problems both without specific context and with a more explicit situation. The two problems were essentially the same in terms of the physics, with two systems brought into contact. Students did poorly on both context-free and context-added items.

Students generally thought that total entropy is always constant, and does not increase in natural processes. 90% of the students expressing a belief in constant entropy fell into one of two major arguments:

1. S_1 and S_2 are unknown, but $S_1 + S_2$ is constant.
2. S_1 rises, S_2 drops, but $S_1 + S_2$ is constant.

After all thermodynamics instruction had been completed, the students were post-tested on this material. Despite being a "reformed" course, there was only a slight improvement in student results, and the "total entropy is constant" idea remained firmly rooted. Students just don't get entropy, even after instruction.

188.05: Longitudinal Waves in a Tutorial Environment – Jack Dostal, Montana State, dostal@physics.montana.edu

A tutorial on longitudinal standing waves (LSWs) was developed and used in class. In addition to the traditional graphical representation of transverse-looking waves in a pipe, the tutorial also used dots to show compression and rarefaction of the medium. Some previous work had tried to avoid the "too much like transverse" problem posed by the traditional representation by having the wave lines pass outside the boundaries of the tube in an attempt to show it was not meant to be taken literally, but students simply thought those diagrams were wrong because they showed the wave passing outside the tube.

The Standing Wave Diagnostic Test drove the development of these tutorials, as it revealed student problems with LSWs. It's difficult to draw LSWs graphically, they tend to be invisible in real world examples, and transverse representations contaminate student thinking.

The LSW tutorial tries to guide understanding of LSWs. In addition to the dots mentioned earlier, they use a Slinky™ with paper flags added every few coils to make the compression/rarefaction more obvious, and to make nodes clearer. Among other things, this demonstration shows that a node does not have a constant pressure.

[Cut most of the end off because of time constraints.]

188.06: Investigating Student Understanding of Wave Behavior at Boundaries – Mila Kryjevskala, University of Washington

The "Propagation and Reflected Waves" tutorial was focused on here. It emphasizes that wave speed depends on the medium, frequency on the source, and that both tie into wavelength.

Posttest performance was good on most items, but not all. Example: a wave passes from medium 1 to medium 2. If you change the wavelength in medium 1 but not

the frequency, what happens in medium 2? Only about half the students correctly answer that there is no change in medium 2, and even only 55% of TAs get this correct.

Would more practice (but not explicitly on the model) help? A bit more information and cueing was given, with the result that about 40% got the core idea right, and 30% were completely correct. Practice doesn't help enough, a new type of instruction is needed.

188.07: Investigating Student Understanding of Control of Variables –

Andrew Boudreaux, Western Washington University

A PBI-based teacher-prep course was used for the subject group.

Given N variables, you control all but one, and if things still change, then this one variable influences results. Can students evaluate this? An example was given in which there were three trials with three variables each, but there were no two trials in which only one variable was free to vary.

Most knew that a control was needed, but few could actually do it. In the example, some intuitively rejected a variable as being unrelated, letting them find two trials in which only one "valid" variable varied. Often, there was too much or too little control, students confused relationships, and tended to let prior bias affect interpretation.

Even highly trained scientists have trouble with control of variables.

Only about half of the students could correctly tell if a particular experiment was badly controlled, but the incorrect responses varied by population.

Does additional science training help in dealing with control of variables? It doesn't seem to. More training results in different incorrect responses, but no real improvement in the rate of correct responses.

188.08: Modeling Student Thinking About Motion in Tutorial –

Brian Frank, University of Maryland

Resource models emerge from the clumping together of smaller scale pieces of knowledge.

For instance, in one-dimensional motion, three pieces would be DT (time goes up as distance goes up), SD (distance goes up as speed goes up) and ST (time goes down as speed goes up). A resource model would chain these pieces together in some meaningful way to allow for analysis of any 1-D motion, such as "DT implies TS" (More distance means more time, more time means less speed). This is incorrect, but it's a model.

Students coordinate multiple resources to reach a compensation argument, or they fail to coordinate and get stuck at an impasse between clashing resources (i.e. "time is slower" that mixes time and speed).

By coding student interviews using these models, it was easier to identify reasoning shifts.

188.09: Sensemaking: Conceptualizing and Coding for "Good" Student Reasoning –

Andrew Elby, University of Maryland (Rachel Scherr presenting)

"Good scientific reasoning" doesn't necessarily correlate with getting the right answers, so we need a way to identify it other than looking at problem solutions. A distinction is drawn between "sensemaking" and "answermaking" behaviors...seeking to understand versus seeking to get the right answer.

Videos of students were observed, and their actions in each one minute chunk was rated on a 7 point scale with pure answermaking being a 1 and pure sensemaking being a 7. Multiple coders then met to compare and discuss, and make categories for the students. There was good inter-rater reliability, with less than 1 point of spread in coding about 80% of the time.

Indicators of sensemaking include, but are not limited to: Mechanistic Reasoning (consider how your actions affect things), Seeking Coherence, Resourcefulness (use outside resources, common sense, analogies) and Independent Reasoning (go off the page, challenge the TA).

Sensemaking is not a behavior, it is a mindset. But it can only be evaluated through behaviors that hint at the mindset.

Teachers want to encourage sensemaking, and researchers can use sensemaking as a useful construct.

General Sensemaking, Formal-System Sensemaking and Language Assimilation are all Good Things that tend to overlap, but no one of them is entirely subsumed within any of the others.

Sometimes the presence of the TA will bump students out of sensemaking and into answermaking, as they enter a frame of "I need to get this right".

Physics and Society Education Crackerbarrel

Opening topic for discussion: the use of environmentally-based/related activities and readings. While there are some advocacy leanings in the proposed curriculum (there was a handout), it tends to shy away from advocacy and covers the environment in a more politically neutral, "natural philosophy" sense.

It's very important to grade based on how actively the students look at the issues, NOT based on the conclusions they reach or the positions they support. That way can lie serious problems, you don't want it to look like you're blatantly pushing one side of a contentious issue.

Illustrative activities and calculations can raise issues without explicitly taking sides, since (as Stephen Colbert puts it) the facts have their own agenda.

Society doesn't really understand experimental technique or controls, which makes accusations of bias stick more readily.

Be ready for accusations of bias no matter how careful you are, but do try to avoid being blatant. It may help to admit to your positions up front rather than letting people try to guess them or make assumptions. However, their own biases may render your efforts moot (i.e. anti-nuke bias can make instruction about the safety of most nuclear power moot).

Selection bias is a real issue as well, the careful picking and choosing of facts to support a previously-arrived-at position. Also, "no one opposes it" is not synonymous with "everyone supports it," but you'll find people making that leap.

You can also approach controversial topics by assigning a non-controversial aspect of them, but leaving it open for students to address whatever other aspects they want. For instance, "Write an essay about the atomic bomb at Hiroshima. Your appendix must include a calculation of the trajectory of the bomb."

The Smythe Report came out just after World War II regarding the physics of nuclear bombs, minus the essential engineering. This could be used in a classroom activity on atomic bombs.

It was brought up that not only does reality have an agenda, but it tends to make that agenda known in unpleasant ways, such as environmental collapse.

Consider risk-assessment lessons in general: car crashes, nuclear power, TSA regulations, etc. There's plenty of grist for that mill.

We need to use education to counter the Somebody Else's Problem effect. For instance, a student was once quoted as writing that global population growth wasn't yet a problem, because there was plenty of room there in North Dakota.

Science involves repeatability. "A new study finds" is a statement that should be greeted with skepticism, especially since refutation studies tend not to make the news. Perhaps use a modification of the classic M&M statistics lab to teach this? The "new study" is a single bag of M&Ms, which finds that, say, 1/5 of the contents are red. Should students believe this without further testing? Do further testing, etc.

[Left early to make it to session 204 on time.]

204: University Supervisors and Cooperating Teachers: Their Critical Roles for Student Teaching (mixed)

204.01: Field Experiences for Prospective Physics Teachers – Ingrid Novodvorsky, University of Arizona (invited)

A teacher prep program for prospective 7-12 teachers was started in 1999 at Arizona, run by core faculty from most of the science departments, plus some from the Education department. All classes were taught in the College of Science, including the pedagogy classes. There are 7 pedagogy courses, 4 of which contain guided field experiences. So far, 54 students have completed this program, and another 80 are in the pipeline.

The earlier courses limit their field experiences to guided observation, working on specific tasks and targets with a mentor and using worksheets to help guide their observations. The advanced course uses an internship model, while the final field experience is student teaching.

Action Research Projects have students investigate an aspect of learning (a la How People Learn) with a class presentation, covering both middle school and high school courses.

The internship is in a senior-level science class off-campus, and includes classroom management responsibilities. Initially the intern observes the classroom for the first few weeks, then uses their observations to make a plan, and a week later returns to teach for seven weeks. They submit lesson plans, videotaped lesson reflections and other portfolio materials to the pedagogy class instructor. Performance in class is 25% of the course grade.

Mentors and adjunct instructors observe the student teachers frequently, with each visit lasting about half a day.

The university supervisors evaluate the following things regarding each preservice teacher: subject matter knowledge, adolescent-development knowledge, coherent curriculum decisions (these are broken into sub-goals), creation of a productive

learning environment, communications and interactions, acknowledgement of complexity, self-reflection.

The mentor teachers evaluate similar things, and also consider student teacher attitude and initiative for improvement.

Summer workshops, regular meetings and mentor orientations are used to help build a sense of community. The frequency of these meetings depends on the level of funding, since high school teachers brought in have to be compensated. During the initial years, funding allowed fairly frequent meetings, but that has dropped off as the initial pool has been spent.

Students in the Scientific Methods course engaged in inquiry science projects based on something "real life". For instance, one person measured the rate of evaporation from their pool over the course of a semester and used that to estimate the loss of water from all pools in Tuscon.

The take-home messages of this talk are: Building community is vital for a program like this to work, classroom teachers need to be seen as **partners** in teacher prep rather than just as a "warm classroom" into which student teachers can be dumped.

Lengthy in-class experiences help catch concerns in time to either fix 'em before graduation or counsel the student to find a new career path. This way, the person with absolutely no stage presence doesn't find this out in their final semester, or worse yet, on the job.

204.02: Essential Support Systems for Emerging Physics Teachers – Sally Luttrell-Montes, University of Washington, sallylm@u.washington.edu (invited)

Essential supports should be tailored to the phases of development a teacher goes through: undergrad, certification, induction (the first two years), professional development, advanced professional development (such as going back for a PhD).

Induction is a very fragile time for teachers, and much of "burnout" happens here.

The "Teachers for a New Era" initiative is a partnership of eleven institutions, providing support for new teachers from undergraduate through induction. Today's talk will focus on the preservice component of this.

The New Era program includes an "Essential Attitudes" disposition check, to make sure prospective teachers have the right mindset...and if they don't, to either help them get one, or steer them out of the career.

Students are eased into field experiences over the course of four quarters. A general orientation in the first Fall term, three weeks of field experience in the Winter term, four weeks in the Spring term, and full student teaching in their second Fall term. This gives them two opportunities to see how the school year begins.

The number of supervisor observations is also increased over time. None in the first Fall, two in the Winter, three in Spring, five during the second Fall.

The student teachers are guided through some prep work before going into the classroom to help their supervisor know what they're doing. Both the supervisor and the CT are involved in the evaluation of the student teacher, and post-observation conferences are used to cover both what did and didn't work. The resulting paper trail provides a record of growth.

The Performance Assessment of California Teachers (PACT) looks to be a promising instrument, and UWash is considering adopting it.

Current reform efforts are extending the support of teachers into the induction phase, but they're being careful not to step on the toes of existing support for teachers in induction. Support is both online and in-person, with new teachers asked to bring a dilemma of theirs along to the in-person meetings. The in-person meetings are also used to look beyond the standards-based materials.

Appropriate and **extended** clinical experiences are vital in preparation.

204.03: Teachers in Residence: University Supervisors, Cooperating Teachers, and In-Service Mentors – Michael Wolter, Muncie Central H.S., mwolter@muncie.k12.in.us (invited)

[TiR – Teachers in Residence. Also, this seemed to be cut down from a longer talk without removing any slides, so he sometimes zipped through material he'd "cut", my notes may be a bit disjoint as a result.]

Ball State University has a "decision point" process to longitudinally track pre-service teachers. The licensing information can be found at <http://www.bsu.edu>.

Decision Point 1 (DP1): Student self-identifies as a professional educator by completing an education course.

DP2: Admission to the teacher education curriculum, takes upper level education courses.

DP3: Admission to student teaching.

DP4: Recommendation for graduation and licensure. This involves an open-audience defense of the student teaching experience (although attendance is often light to non-existent).

The Physics department has its own Teaching Student Handbook, with details on what the DPs mean in the case of the department. Faculty advisors help track the process.

The TiR is a high school teacher who helps the university faculty work things out and arrange CT opportunities. The TiR works on the university campus and is replaced at their high school by a temp, who works closely with the TiR to make sure things run smoothly.

PhysTEC is the Physics Teacher Education Coalition, which works with TiRs.

A TiR is inserted into "Introduction to Science Education" courses, and reveals "behind the scenes" stuff to students, the sort of thing that isn't often covered in pedagogy courses.

The process helps build community, and the CTs get to pick student teachers from the crop of education majors, since they know who's there and what they're capable of thanks to the TiR. TiRs work to reduce isolation and the subsequent attrition, and TiR mentoring has been shown to help with retention. It also reduces the "pay your dues" pseudo-hazing that can happen to teachers in induction.

When a TiR goes "home" the results can vary, but they try to minimize negative effects.

All pre-service teachers must undergo regular background checks for felonies, by state law.

Ball State's guidebook may end up standardizing student teaching nationally.

TiRs who are currently not in residence (i.e. between years of service on campus) often also act as CTs. While they're in residence, they're university-funded at some universities, but not yet at Ball State.

TiRs are an essential ingredient to change.

School district funding is needed to support mentors.

[A number of recommendations were quickly run through at the end.]

204.04: A Student Teacher Effectiveness Reporting System – Carl Wenning, Illinois State (contributed)

STERS – Student Teacher Effectiveness Reporting System

NTSA standards drive the development of STERS.

STERS covers seven content areas. These are not science topics, but rather things like "Science in the Community".

NSES – National Science Education Standards.

STEP – Student Teacher Effectiveness Plan, a four step process.

[Yes, most of my notes are acronyms. Most of the **talk** was acronyms, and I lost track of actual meaning about halfway through and stopped taking notes, sorry.]

Wednesday, January 10

235: Teacher Learning

235.01: What Did We Learn From The Teachers' Journals? – Hamed Kastro, University of Texas at El Paso

[Cancelled, Hamed wasn't present.]

235.02: Support for New Physics Teachers – Brian Adrian, Kansas State University, badrian@phys.ksu.edu and <http://www.physicspathway.org>

The PATHWAY project is an ongoing attempt to create an online resource that combines a video library with a set of "synthetic interviews" where a querent can ask a question and get an interview clip from an expert that more or less answers that question. It's meant for use by instructors rather than by students.

Due to some issues with conflict between new and old software, they're having to go back and update all the older material to work under the new standards, since the two systems don't want to play nice together. So this has caused a delay in the addition of new material. Hopefully this will all be taken care of by the end of January 2007.

They will be adding 8 hours of Paul Hewitt workshops, a lesson on cartooning, some contributed videos (such as the IR photography video mentioned in the notes from the 2006 AOK section meeting).

About a thousand questions are currently answerable, plus numerous reasonable restatements of those questions. The number should double soon, as they add second semester material.

So far, 2500 questions have been asked by users, although that includes "test" questions Adrian himself has asked to make sure things work. The breakdown has not changed since the AOK meeting talk.

The focus of users so far is not really on activities and assessment, which is where the makers would like it to be. A survey of users is planned to see why so few questions are asked regarding those topics.

235.03: Using Facet Clusters to Map Learner Modes of Reasoning – Stamatis Vokos, Seattle Pacific University, working with FACET Innovations of Seattle.

We need teachers with deep subject matter preparation **and** a knowledge of what modes of learning are unproductive, plus preparation in flexible methodology.

FACET Innovations is developing a web-based formative assessment tool for use in conjunction with extensive professional development of high school teachers.

Assessments are both multiple-choice and open-ended. Teachers get more or less realtime feedback on their students' progress (it's meant for use between classes, not during). Branching questions are used, and there's a diagnostic agent for tagging evolving student ideas.

<http://www.diagnoser.com> has the Diagnoser Project tools.

Empirical frameworks are clusters of facets, which include explicit learning goals and the intuitive ideas students have.

Caveat: student conceptions are overlapping and non-hierarchical, but the tool makes the simplifying assumption that they're sufficiently distinct and hierarchical in practice.

An example of a crucial skill measured by this tool is proportional reasoning.

These are facets a la Minstrell. A Cluster is a group of facets in a given skill or concept. Using clusters helps with diagnosis of student progress.

[Moved too quickly through the remaining examples and data to take notes.]

235.04: Using Facet Clusters to Guide Teacher Professional Development – Lane Seely, Seattle Pacific University (sequel to 235.03)

Sample problem: given two objects on a balance that is level, what can you say is the same about them based solely on this measure? Students were specifically allowed to pick more than one answer on the multiple choice (which included things like mass, volume, density, etc).

In workshops with high school teachers, they raised the issue of cognitive dissonance in the question, as well as test-taking sophistication (the idea of a "choose several" question is somewhat more advanced than many students were used to, plus the wording of the question was potentially tricky).

The question was modified in response to these concerns, further emphasizing some parts (like "based on this measure") and made the question a simple multiple choice, with the more popular dual and triple choices as single options now (i.e. options like "mass and volume" were presented).

With fewer actual distracters (some of the options from the original question were left out to make room for the dual choices), scores actually went down. However, by making it clearer that dual choices were available, more students picked incorrect combo answers (the correct answer was only the mass). However, when you counted all answers that included mass as an option, the total score was higher than before. The lack of quite so many total options made it clearer that mass was a possible right answer.

Professional development should be two-way...take advantage of what the teachers already know, don't assume they just need to take from you. It helps to create a safe environment for everyone to work in.

235.05: Teaching About 21st Century Energy Sources to Pre-College Students and Teachers – Andrew Zwicker, Princeton Plasma Physics Laboratory

Given that CO₂ levels are increasing by 1.9ppm/year, we're about 90-140 years away from a critical point. We need to change how we get our energy if we want to prevent this, and find a way to stop pumping so much carbon into the environment. Solar, wind, and fusion are foci for production, and hydrogen for storage/transport.

The PPPL is engaged in various outreach education programs regarding alternative energy on all levels from K-20. For example, middle school students participate in a fuel cell model car race with competition at the national level, combined with workshops for middle school teachers.

Another program is the Scientist-In-Class month-long experience covering grades 1-6. The first year solar energy is covered, the second year wind energy is the topic, and students work on projects as part of the program.

They're also doing summer professional development workshops called Plasma Camp around the country, with a week-long plasma-centered program that runs for 1-3 summers per participant. Teachers get funding to buy equipment for use in their classrooms. About 70% of participants have institutionalized the curriculum learned at Plasma Camp.

[Other examples were given, but he was running out of time and flash through them too rapidly to take notes.]

235.06: Conceptual Dynamics: Comparing Inquiry and Direct Instructional Designs – Adriana Undreiu and Betty Adams, Western Michigan University.

"Conceptual Dynamics" in the title refers to dynamics treated in a conceptual way, not the dynamics of concepts. The study compared inquiry-based and direct instruction methods, investigative versus confirmatory.

They developed a dynamics module mainly covering N1L, N2L and some vocabulary, and approached it in both inquiry and direct fashions. They kept delivery, equipment and topics as similar as possible except where specifically varying as required by the relevant method. Sequence of topics, the role of the teacher, and the experience of the students in class were different between the two groups.

As of now, the experiment has only been set up, and they hope to have results in 4-5 years.

[As an aside, given the debate over direct instruction on PhysLrn-R that has taken place in late January 2007, I wish I'd gotten more specifics regarding what they meant by direct instruction. I'm not sure they gave more specifics, but if they did, I didn't take notes on it. It's possible that they're using a strawman form of direct instruction, I don't know.]

235.07: Comparing Understanding of the Nature of Science in Science Courses – Rhett Allain, Southwest Louisiana University (title different from the one in the program)

EBAPS scores for traditional and inquiry-based courses were matched up and compared as best as was possible. The inquiry courses showed a greater understanding of the nature of science.

By "nature of science," he means what is or is not science, the process of science, and critical thinking in general.

The subscales are still being analyzed, the current results are just based on overall EBAPS scores. The five point scales have been rebinned into "agree with expert/neutral/disagree with expert". This loses detail but improves confidence in the results.

Two semesters of the following courses were examined: traditional algebra-based physics, traditional introductory astronomy, and an inquiry-based teacher preparation course. The traditional courses showed no real change (effect size less than 0.1), while the inquiry-based course had an effect size of 0.74 and an absolute gain of 1.19 [and if that's on the rebinned 3 point scale, that's pretty impressive...still not bad on a five point scale].

One of the astronomy sections explicitly lectured on the nature of science, but despite students being told the "answers" for the EBAPS there was no real effect.

The inquiry course used the Goldberg and Otero "Physics for Elementary Teachers" curriculum, and no EBAPS "answers" were explicitly given.

The data still needs to be mined for other interesting results.

235.08: Integrals for Pre-Service Elementary Teachers: Approximating Seasonal Solar Radiation Differences – Paul Ashcraft, Penn State Erie, Behrend College

Going low tech, Ashcraft engaged in "extremely guided" inquiry in teaching the reasons for the seasons. While most people can say that the seasons happen because of the tilt of the Earth, often that's all they can say, and they can't explain why the tilt matters. However, showing why the tilt matters involves integrating over the rate of energy received on the ground to find the total energy input, and not many elementary education majors have the calculus skills to do this. Nor would any of their future students. This makes it harder to avoid simply telling them the answers.

To get around this, and let the students do calculations themselves that are reasonably good yet within their abilities, all curves were approximated as triangles. Zero at dawn and sunset, peaked at noon. They can either be given the peak values from an almanac, or use light meters to take measurements at noon and then multiply by a trigonometric function based on the angle of the Sun. Graphs are made by hand rather than using Excel, so that the auto-scaling function on Excel graphs doesn't obscure how the dimensions change throughout the year. The area is easy enough to find, just half the base times the height, and comes out to about 3 kWhrs for winter in PA, 6 kWhrs at the equinoxes and 9 kWhrs in the summer.

Students looking at the graphs can clearly see how things change over the course of the year. The base is the length of the day while the height of the triangle varies with the angle of the Sun. It gets taller and wider in the summer. You can also take into account the change of distance from the Sun over the course of the year, a variation of about 3.5% either way.

Results have been encouraging. The lesson seems to have sunk in, and more students showed understanding of the reason for the seasons than in a didactic class covering the same topics.

First Annual PER Symposium – Overcoming Gravity

[This started late, and I left after less than an hour to attend session 248. This was mainly a call to action sort of thing, rather than discussion of results, but I don't think it had really gotten going by the time I left. Still, I took some notes based on the opening remarks that I did stay for. All things considered, though, I think the title was inappropriate. It seemed focused on the value of physics education, not physics education research per se.]

The aim of the Symposium is to start a dialogue, with AAS as well as AAPT, on how physics education is linked to boosting national competitiveness.

Washington state is at a critical time in education, as are most states. Opportunities and challenges alike abound. The Gates Foundation is putting a lot of funding into both pure science and science education research.

We shouldn't shy away from politics, as we have much to offer.

Rhetoric is not being turned into educational policy, in large part due to a lack of a sense of urgency. However, in states where a broad consensus that "something needs to be done" does exist, more does get done.

248: Theoretical and Diagnostic Issues

248.01: Diagnostic Tests for Entering and Departing Undergraduate Students – Chris Waltham, University of British Columbia

Essentially, this is about pre- and post-testing for the entire program, beyond just the course exams. They want to allow a lot of latitude in responses, avoid teaching to the test, and keep Big Goals in mind rather than the minutiae of course materials.

They have considered using Redish-style problem classes (as in Teaching Physics, 2003), favoring the use of representation-translation problems.

The trial groups for this study were 10th grade "science challenge" participants, UBC "Science One" students (an elite course focusing on excellence in both science and writing), and graduating physics majors who had expressed an intention to go on to teach.

Even the graduating majors didn't get a perfect score on the test, although the types of errors changed with advancing experience. Some items, like those on the greenhouse effect, showed poor performance at all levels. The scores on this instrument were badly correlated with overall course grades in science classes.

An example of a persistent problem is student responses regarding Solar radiation. Because the media reports the UV index, many students claimed that the Sun's main form of radiation was UV (this came out in interviews).

Also, "unsophisticated" questions tend to trip up everyone, demonstrating lack of mastery. The cram/pass/forget style of succeeding in school is **too** successful for them, and they never really learn the material.

248.02: Student Preparation, Aptitude and Performance in a First-Semester Algebra-Based Physics Course – Robert Hill, Ball State University

This is a PhysTEC project talk, on what they have found so far. None of the attempted remediation was discussed, but it has been done.

Looking at the school's three biggest majors (pre-med, biology, tech/industrial), they found distinct distribution curves for physics course grades. Pre-med students tended to peak in the A range, biology majors in the B range, and tech students in the C range, reflecting the different priorities of those students more than anything else.

Almost half of those taking "freshman" physics courses at BSU are doing so as juniors and seniors...seniors alone account for 45%! The later students delay taking physics, the better they seem to do at it, although a background in high school physics is also a strong predictor of success.

Looking at some of the less popular majors, non-physics-specialty education majors do about as well as pre-med on course grades (physics majors and physics-specialty education majors take a different course).

On the FCI, overall gains (including both traditional and reformed sections) are about 0.23, with education majors and tech majors sticking pretty much right on top of the mean. Pre-med majors get gains of about 0.30, while biology majors clock in at 0.20.

The correlation between FCI gains and GPA is $r = 0.51$ for majors with at least ten people in them. The FCI pretest and SAT Math score have $r = 0.9$, while FCI gains and SAT Math correlate at $r = 0.7$ or thereabouts. Other research shows that FCI pretest and gain correlate at $r = 0.998$, however, which makes the SAT Math effect a bit odd, more investigation is needed.

248.03: Comparing Item Responses on the FMCE and FCI – Karen Cummings, Southern Connecticut State University

This is based on work that has been ongoing since 1998, and a paper is promised to be forthcoming real soon now.

About 1700 students at RPI were studied over the course of eight years (and only RPI, so be wary of overgeneralizing). Both the instructors and mean gains on FCI and FMCE have varied over time, with gains showing a trend of going up and then going back down.

FCI and FMCE pretest scores correlate positively, as do posttest scores, with the spreads staying about the same. Fortunately, the main clump of data does move upward between pre and post. There's no real difference in correlations between FCI and FMCE pre and post, so results from here on out will combine pretest and posttest numbers.

The overall correlation is $r = 0.78$, with a slope of $m = 0.54 \pm 0.02$ for a graph of percentage scores (FMCE on the x-axis). Most data lay above the $m=1$ slope line through the origin [the FCI-intercept was not given, but presumably was positive].

The FCI score was considered high if it was greater than 60%, while the FMCE score was considered low if it was below 40%. Out of 3400 data points (pre and post for 1700 students), there were 406 points in the "High FCI/Low FMCE" (or HILE) group. There were only 6 points in the "Low FCI/High FCME" group (FCI below 40%, FMCE above 60%). So...not particularly symmetric, there's clearly something about the two instruments that makes the FCI harder than the FMCE.

What on the FCI do the HILE group do well on? Looking at the data, it appears that these students do well on 2-D motion and freefall, neither topic of which is on the FMCE.

Looking at high-FMCE students in general, they seemed to have trouble on the two "car and truck" N3L items, the forces-on-objects items, and the box-pushing items #25-26. But, in general, doing well on the FMCE also meant doing well on the FCI, while the reverse was less often true.

248.04: Exploration of Epistemological Beliefs in a Summer Science Program for High Achieving Students – Sebastian Cormier, CCNY

A 17 item epistemological survey was created based on items from the MPEX, and administered on the first and last days of class. A science question about whether the Earth went around the Sun or vice versa was also asked.

Students generally answered the science question correctly, but gave iffy reasoning, such as circular logic or appeals to authority.

Students were asked to build geocentric models in class, to see how oddly they worked. Those who built the models were better able to support their answers on the posttest.

A five point rubric was used to rate student reasoning, where an argument from authority was scored as a 1. The gain in reasoning scores on the heliocentrism question was $\langle g \rangle = 0.60$. Gains on the epistemological questions were much smaller, 0.06 on average and 0.11 on the Independence scale, but given that many classes show losses on the MPEX, that's not necessarily a bad thing.

Teacher ratings of student epistemology were lower than the survey ratings, and the correlation between the two was low.

248.05: Rate of Learning Models, Mental Models, and Item Response Theory or "How Prior Knowledge Affects Learning" – David Pritchard, MIT, dpritch@mit.edu

[This was a math-dense talk that really should have been saved for a time when 20-25 minutes were available for it. Rather than just transcribe the somewhat incoherent notes I took, I will try to summarize the essence of what I think Pritchard was talking about.]

This was essentially an attempt to use differential equations to model the data we already have on student learning, looking at two fairly simple models as a basis.

In the tabula rasa model, the rate of understanding depends only on the size of the "unknown knowledge" space. As long as what you're teaching hits $U(t)$ (the space of what is unknown) instead of $K(t)$ (the space of what the student already knows), there's a chance of it sticking. $dU/dt = -\alpha_s U(t)$, which has an exponential solution. This is dubbed the "shotgun" approach to teaching.

In the basic constructivist model, learning only happens when material aimed at $U(t)$ is close enough to $K(t)$ that connections can be formed. $dU/dt = -\alpha_c U(t)K(t)$, which has a Fermi solution. This is dubbed the "connected" approach to teaching.

Looking at the Hake data, the shotgun model fits it pretty well, but the connected model curves away from the trend line pretty noticeably. However, looking at some data from MIT, the connected model fit better than the shotgun model.

The conclusion was that how you teach determines how they learn, and that there needs to be a good fit between teaching style and testing style. If you teach to the test, then the shotgun model fits pretty well. If you require students to be able to interpret the results, the connected model fits better.

[During discussion, Redish brought up the Zone of Proximal Development, and how this can put a HUGE kink in the analysis. Plus, I got the feeling that the people in the room did not in general seem to accept that either simplified model (shotgun or connected) was really valid.]

248.06: Transfer of Learning: From Physical Models to Understanding Complex Phenomena – Bijaya Aryal, Kansas State University, bijaya@phys.ksu.edu

Part of the Modern Miracle Medical Machines (MMMM) project, specifically looking at Positron Emission Tomography (PET).

Individual teaching interviews were performed in Spring 2006, and group teaching interviews in Fall 2006. Two physical models were used in an attempt to help scaffold students to an understanding of how PET works.

The first involved two dynamics carts on a track behind a barrier, with a spring used to force them apart. Students would measure when the carts emerged from behind the barrier to figure out where they had started. This models how the pairs emitted in PET let you determine where the event occurred inside the body.

The second activity used a series of LEDs inside a translucent cake box. Pairs were lit up at intervals, creating a virtual center of activity inside the box where lines drawn between the pairs would cross (more or less...some ambiguity was deliberately introduced). This models how PET scanners use the results of many pair events to determine more precisely where the activity is.

Students were then asked questions about PET in specific to see what, if anything, transferred between the models and the real thing. Students working alone were largely unsuccessful, while groups were mostly successful in qualitative descriptions, with nearly half of the groups successfully answering quantitative questions as well.

In the solo work, spontaneous transfer from the models to PET happened in four cases, while six others semi-spontaneously transferred (there was a link to underlying principles) and three more had to be cued. In the group work, 7 groups had spontaneous transfer and one semi-spontaneous. No groups needed to be cued, but it was hard to say what percentage of group members needed to be cued by peers.

The group work definitely helped with qualitative reasoning, and the models helped both in solo and group work. Further work hopes to follow up on individual participants in the group work to see how robust the results were when individuals are not supported by the group.

248.07: A Transformed Introductory Mechanics Lab Focused on Developing Reasoning – Vincent Colette, Loyola Marymount University

Cancelled

248.08: Context-Independent Problem Categorization to Cultivate Real Problem-Solving Skills – Kathy Harper, the Ohio State University

Cancelled (Kathy was at the first couple days, but had to leave early.)

248.09: Discussion of the "R² and Correlation Coefficient" Survey – Jeff Marx, McDaniel College

[In which we are all made to feel kinda foolish. While I ended up not turning in my survey, what I had completed of it matches the overall results he got.]

At the Syracuse meeting, Marx distributed a survey on correlation coefficients to back up a hunch he had. It asked a series of questions about correlation and goodness of fit, given various data sets, including one set that was just a 45 degree rotation of the previous set.

In general, people treated R² as being synonymous with how well the data "hugged" the regression line, while some treated it as being related to the steepness of the slope of the regression line, but it is neither. Nor does it say anything about effect size...you can have a very high correlation but a negligible effect (i.e. R² = 1 for something that tells you that for every million dollars more you spend you will get a return of five dollars on your investment may be exact, but not a resounding endorsement for that particular plan).

Overall, while correlation is useful, it's not as useful as most seem to think it is, and shouldn't be the only thing you report in your data. Instead, it's far better to report the slope along with a confidence interval, or simply report the slope and the standard error of the slope. The standard error of the slope divided by the slope is a much better indicator of "hugginess" (as it ended up being called during discussion).

Essentially, slope tells you whether you should care, while standard error of slope divided by slope tells you how much you should trust the results.

[And thus ends my notes for the 2007 AAPT/AAS National Meeting. For those curious, my original handwritten notes took up 55 pages (single-sided) of a wide-ruled notebook. If I'd taken notes at any plenary sessions, posters or award ceremonies I might well have run out of space...I guess in Greensboro I'd better bring along a backup notebook!]