NEWSLETTER

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My Experiments with PER

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Editor's note:
This is the first in a series of articles by Chris Meyer describing his experiences implementing a Workshop Physics program. To help guide Chris's ensuing articles, please give him feedback or ask him questions by emailing him directly.

What physics teacher doesn't like a good experiment? Over the past few semesters my classroom has become one elaborate trial in an experiment to determine whether there is a better way to teach grade 12 physics. My attempt has been a new physics course built around concept-focused group activities with an almost complete elimination of the traditional lecture.

Around seven years ago I became acquainted with the body of pedagogical work called Physics Education Research[1] (PER) after attending a presentation[2] by Edward F. ("Joe") Redish, one of PER's leading lights. I discovered a whole new world of strategies and techniques that I began to incorporate into my class. Despite many small successes with these techniques, in general things didn't work out. My application of the techniques was inconsistent and my expectations of students were continually changing and sometimes unclear. Students never had a chance to 'get the hang' of things. I decided it was time for a radical change that brought everything together into a cohesive framework for the entire course.

The inspiration for the transformation of my course comes from a variety of sources, but primarily from the Workshop Physics[3] program developed by Priscilla Laws at Dickenson College. She and a number of other pedagogical leaders have established an extensive body of research. Setting this work apart from other pedagogical studies is the natural impulse of physicists to quantify their research. They tested new teaching techniques against a variety of standardized and widely used assessment tools, the most well known being the Force Concept Inventory (FCI)[4]. The results of this work point strongly to three conclusions:

1. Lecturing, even with new pedagogical supports, is a relatively ineffective way to teach physics;
2. Students benefit greatly by focusing on concepts and working in small groups; and
3. Quality beats quantity. Teachers should aim to cover less material, but in greater depth.

From Inspiration to Implementation

The next challenge was to figure out how to implement such a program in my classroom. While my source of inspiration was the Workshop Physics program, there was no single resource or pre-made map that was directly applicable to my situation. Most of the PER resources have been developed in the United States for the college or university levels. Many resources had to be adapted for the Ontario curriculum, to eliminate the use of calculus, to work around differences in equipment and to meet the needs of my particular school and students.

The best way to explain the workings of my course is to describe how students approach a new concept. They go through a process of group activity, text readings, homework problems, and finally group problem solving. The group activity is the typical starting point. The emphasis is, as much as possible, on concrete investigation. This offers students direct experience with the physics at hand, which helps them to make sense of the emerging concepts. They study the patterns, offer explanations and draw simple conclusions that lead them towards the mature ideas.

[1] *Physics Education Research Central*: http://www.compadre.org/per/
[2] *Teaching physics: figuring out what works*, Edward F. Redish and Richard N. Steinberg, *Physics Today* **52**, 24-30 (January, 1999), http://www.physics.umd.edu/perg/papers/redish/pt.htm
[3] *Workshop Physics Homepage*, http://physics.dickinson.edu/~wp_web/wp_homepage.html
[4] The Force Concept Inventory http://modeling.asu.edu/R&E/research.html

Interspersed with class discussions, these activities take up the full class time.

One example is an activity introducing pulleys. Students begin my measuring the force of tension with a variety of pulley configurations and draw conclusions about tension in a string and how pulleys affect it. Then they apply those conclusions to an exploration of an Atwood machine. For homework, a reading is assigned which helps them relate what they observed in class with the framework of physical laws and the mathematical formalism found in the text. This is followed up with a small set of practice problems. Questions are generally chosen to require students to further unravel the concept and are less frequently of a 'plug and chug' variety.

Finally, students participate in a group problem solving session that sums up the ideas of a number of classes. Here they work on a context-rich[5] challenge typically involving the physical measurement of an apparatus, planning and solving a problem on paper, and then verifying the results using the apparatus – seeing if their theoretical prediction holds up. Lecture time in class has been pared down to the bare essentials necessary to start off an activity, to the summary of the day's work, to the clarification of a textbook reading, or to the outline of a problem-solving tip. This seldom consumes more than ten minutes per class.

My students' experiences have changed considerably from mostly listening and repeating to continuous investigation, discussion and explanation. They are wrestling with physics ideas for a good 60 minutes per class – especially on the group problem solving days when they really sweat! The transition to this new classroom 'culture' can be challenging for student, may of whom might be quite comfortable and "successful" with the traditional ways and are not used to the demands of my new regime. I spend a good amount of time at the start of the course explaining how group structure, dynamics, and roles work and how to avoid typical problems. I teach them the learning skills that are necessary for success in an environment of greatly increased student responsibility. Doing this reduces the number of students who may feel lost, resentful or under-served by their teacher in this new format.

My experiment with PER is ongoing and hasn't yet reached the quantification stage. At the moment, I judge its success mostly by my observations and feelings. A few positive outcomes seem quite clear, however:

1. Student engagement in class is much improved. This may be due to the appeal of working in a social environment with their peers, and to the many 'hands-on' activities, all of which may appeal to a wider range of learning styles. Supply teachers consistently note an unexpectedly high degree of diligence.
2. Students are constantly using their own words to describe physics verbally and in writing, greatly improving their physics literacy.
3. Traditional student problem solving skills remain very high, even though I rarely model a problem solution in class.
4. Course enrolment is very stable this past semester – the attrition has been less than 10% amongst 89 students.

I have found this change in teaching quite a gratifying development for me and I heartily encourage others along this path. I am currently working with the OAPT to make my complete set of resources for the grade 12 course available online. Perhaps the best way to start your own experiments would be trying out a few of these resources. Then maybe you will take the plunge and say farewell to lectures and the old way of teaching!

Upcoming Events...

STAO2010
Inclusive Science:
Difference, Diversity and Equity
DoubleTree by Hilton – Toronto Airport
November 11 – November 13, 2010

Physics at Work
OAPT Annual Conference
McMaster University
May 12 – May 14, 2011
Visit www.oapt.ca for updates.

OAPT Grade 11 Physics Contest
Visit www.oapt.ca for contest details.

OAPT Newsletter
We continue to encourage teachers to contribute articles. Visit www.oapt.ca for contact

[5] *Cooperative Group Problem Solving*: http://groups.physics.umn.edu/physed/Research/CGPS/CGPSintro.htm

Everyday Einstein: The GPS and Relativity

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Did you know that the GPS must take into account special and general relativity?
If engineers didn't adjust for the motion of the satellite relative to the receiver on Earth the receiver's clock would gain 7 microseconds each day due to special relativity. Reverse adjustments to compensate for the weaker gravity at the high altitude of the satellite (general relativity) prevent the loss of 45 microseconds per day. Who cares about 38 microseconds? You do. The GPS receiver calculates your position using $d = vt$. The radio signals travel at the speed of light, causing a timing error of 38 microseconds to translate to a distance error of more than 11 km! Without careful attention to the effects of both special and general relativity, the GPS simply would not work.

A useful resource about an amazing technology
The Perimeter Institute`s latest resource for physics teachers deals with this everyday application of relativity. This resource consists of a six-minute video and a generous selection of worksheets and activities designed to make this resource useful in a variety of places in the curriculum. There is a hands-on activity in which students emulate the work of the GPS system using the Pythagorean theorem, $d = ct$ and large-scale maps. This is a nice fit for grade 9 astronomy, grade 11 kinematics or grade 12 Earth & Space science. In grade 12 physics the most obvious connections are with orbital energies and special relativity, but it might best be used when dealing with frames of reference. Suggested activities involving leaky bottles of water tossed into the air and trays whirling around with glasses of water on them are fun (and only slightly messy) examples of accelerated frames of reference. They connect directly to Einstein's equivalence principle, the `happiest thought` of his life. Concept questions following these activities allow the students to do what Einstein did in 1908: predict that a gravitational field will slow time. Who knew that general relativity could be made so simple?

Get your FREE copy now!
You can order this free resource from PI`s website: **www.perimeterinstitute.ca/Perimeter_Inspirations/General/Perimeter_Inspirations/** .
Also keep an eye out for after school GPS workshops in southern Ontario this fall. At these events you can enjoy some social time with other physics teachers, make and take some equipment and enjoy asking difficult questions of the presenters :) For dates and locations of these workshops visit **www.oapt.ca**.

The Demo Corner

The Belt-Hanger (1987 Revisited)

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Submissions describing demonstrations will be gladly received.

This article first appeared in the OAPT Newsletter in 1987. It is being repeated here for three reasons: the demonstration is a classic, 1987 was a long time ago, and now this demo (and others) can be seen online (use the link at the end of the article).

One category of good physics demonstrations involves the "disorientation" or "disequilibrium" of students. The demonstrations in this category cannot be explained by most students, and thus serve to disorient the students into a state of disequilibrium from which they wish desperately to escape.

Such demonstrations pique the students' curiosity and gain their attention. Some students have been known to throw up their hands and say that such a demonstration can be explained only by magic. At this point, the

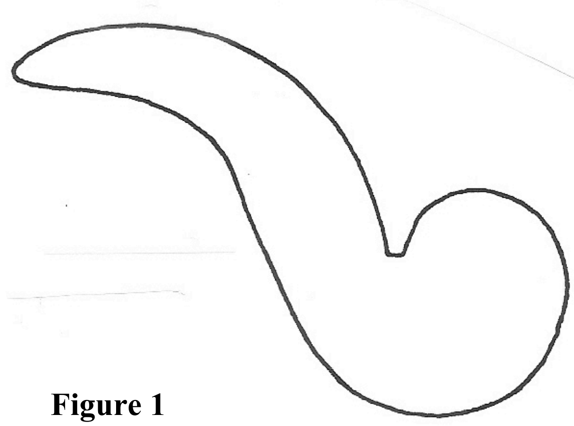


Figure 1

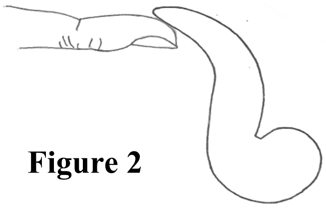
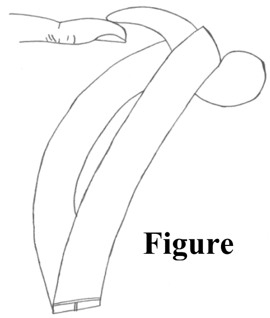


Figure 2

students are like putty in the teacher's hands, and they are eager to learn the real explanation.



Figure

The belt-hanger described here is a nice disorientation demonstration, and it is cheap to make and easy to use. Figure 1 shows a belt-hanger in (full-size) cross-section, and can be used as a pattern from which to make your own belt-hanger. It can be made from a variety of materials: wood, metal, thick cardboard, etc. The ideal thickness is about 1 cm (the aluminum one I have is 9 mm thick).

Once the belt-hanger has been made, position it on the end of a fingertip as shown in Fig. 2. It is unstable in this position and falls to the floor.

Now take a belt (preferably a firm leather one with a reasonably large buckle), and fasten the buckle so that the belt forms a closed loop. Place the belt on the hanger (on your fingertip) as shown in Fig. 3, with the buckle at the bottom of the belt.

Instead of the hanger and belt falling to the floor, the entire system is quite stable! For added effect you can swing the hanger and belt gently from side to side, or place it on the edge of a table or the top of a door frame.

Students are very surprised that the hanger is unstable by itself, but stable when the belt is hung on it.

HOW IT WORKS — If an object (which is free to rotate) is to be in stable equilibrium, the centre of mass (CM) must be below the pivot point.

When the hanger alone is placed on a fingertip, it is impossible for the CM to be position below the pivot point without the hanger sliding from the finger and falling. (The pivot point is just the contact point between the hanger and the finger.)

When the belt is on the hanger, the CM of the system (hanger + belt) is now positioned somewhere in the middle of the loop formed by the belt, and it is "easy" for the CM to be under the pivot point, with stable equilibrium being the result.

WHY DO IT? — First, it engages the students' minds in attempting to explain a physical phenomenon. Second, although centre of mass is not a topic which is usually not taught in any depth at the high-school level, it is useful to point out to students that the acceleration $\boldsymbol{a}$ in Newton's Second Law ($\Sigma \boldsymbol{F} = m\boldsymbol{a}$) is the acceleration of the CM of the object, and it is then nice to have at least one demo related to CM.

At the university level, the topics of CM, torque, stable and unstable equilibrium are considered in detail, and CM demonstrations related to equilibrium are very useful.

WEBLINK — To see this demonstration performed, go to www.physics.uoguelph.ca/outreach/ and click on "Videos" and then "Balancing act." To see another CM demo, click on "Centre of Mass".

The President's Corner

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Preparations for the annual spring OAPT conference are already well underway. McMaster University will host the conference, running May 12-14, 2011. Online registration will be available very soon.

The *OAPT Newsletter* has added eager volunteers brimming with new ideas. One suggestion is to offer the Newsletter as a pdf, reducing our carbon footprint and allowing for colorful editions. Watch for a survey to follow.

The annual Grade 11 Contest is in transition. A robust new server and IT support, again courtesy of U of T Electrical & Computer Engineering, is being adopted to address past problems. We'll keep you posted!

Many thanks to two Executive members who are taking a hiatus – Marianne Franklin as *Newsletter Editor* and Nick Keehn as *Contest Manager*. Shawn Brooks is switching portfolios, from *Treasurer* to *Contest Manager*. Thanks to these and our many volunteers who keep the OAPT fresh and vibrant.

The OAPT exists to support physics teachers and promote sharing of ideas and talents. Many hands make for light work and a strong association. Email me to share your ideas, offer your services, or provide constructive criticism.

I feel privileged to collaborate with so many dedicated physics educators. It's truly a labour of love. Have a great year, everyone.