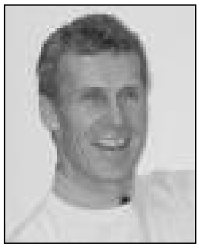
Dave Doucette's P.E.R.* Corner

(*Physics Education Research)



««« By Dave Doucette

Dave has been writing and presenting workshops on education-based science instruction for two decades. His workshops usually operate under the acronym of 'Getting the HOTS' (high-order-thinking skills) for a variety of topics with a physics emphasis. He currently teaches physics at Richmond Hill HS in York Region DSB. He may be contacted at **david.doucette@yrdsb.edu.on.ca**

Curriculum Connection: Physics, Grade 11 – SPH3U; can be adapted for Grade 10 motion unit.

This article was originally published in the Ontario Association of Physics Teachers *OAPT Newsletter*. It has been edited for *Crucible*.

Where are we now?

The current state of science literacy is lamented in America's Lab Report, 2006[1], an insightful look at the current state of science literacy in North America. The chair of the committee is 2001 Physics Nobel Prize winner Carl Weiman, (previously University of Colorado, now at University of British Columbia). The report cites primary reasons for failure to achieve improved literacy and points to current research for promising steps forward.

Carl Weiman's presence on this committee is not coincidental. Obviously an outstanding researcher and thinker, he is also a committed PER supporter. Under his auspices, the University of Colorado physics education group has developed a public domain site offering research papers and excellent java applets to aid with physics instruction internationally. I urge all physics teachers to check out this marvelous teaching aid. Go to http://phet.colorado.edu/web-pages/index.html .

I have summarized some key points on the report recommendations in the following concept map:

Principles for Design of Highly Effective Laboratory Experiences

Sequenced into the Flow of Instruction
laboratory activities are explicitly linked to prior and subsequent learning experiences

Clearly Communicated Purpose
transparent learning goals for laboratory experiences maximize student engagement and learning

Integrated Learning of Science Concepts and Processes
content and process are seamlessly woven in learning activities

Ongoing Discussion and Reflection
students need opportunity to discuss and reflect, make sense of data, refine and clarify mental models

At first blush, teachers may feel they are doing all of this. In fact, they often are. That is the problem – teacher centered learning! Instructors are often the only ones in the classroom connecting the distinct modes of thought required in a physics classroom: algorithms, terms and concepts, graphical analysis, free body diagrams. These *habits of mind* are processed in separate areas of the brain and do not simply cross-connect. Students must be given multiple opportunities to make the linkages themselves, through sequenced activities and guided discovery worksheets, in sequentially richer contexts. These need to be coupled with opportunities to discuss and reflect. It is not sufficient for these connections to be lucidly explained by a passionate instructor. It is best achieved by being 'a guide on the side, not a sage on the stage.' As leading researchers are quick to advise: *"Student talk is far more important than teacher talk."*[2]

This article looks at a sample laboratory activity which is easily woven into the learning cycle and which attempts to gain 'cognitive engagement' of students by posing a fun challenge. A guided discovery worksheet helps students link previous – or current – learning to the activity. The group paradigm encourages student discussion in a non-threatening atmosphere.

Does it Look Like?

Below is an example of a diagnostic activity used with grade 11 physics. Materials required are either battery-driven constant motion cars [WalMart], or dollar-store 'wind-up' cars, and dollar store plastic bowling pins. Each team is provided a car and a single bowling pin, set up on a flat surface – the floor will do in a pinch! Teams score points depending on the distance from the car to pin – the greater the distance the higher the point value. I make up the distances and the scores on an ad-hoc basis, depending on the available space and the reliability of the cars. Five minutes are allowed for practice trials before the competition gets underway. During the competition, each team member is allowed five shots, scoring only if the car successfully knocks over the pin. Members decide on the placement – and thereby the point value – before each shot. I limit the time for 5 shots to about 1 min per player.

Pitching it as a friendly competition increases student engagement *(clearly communicated purposes).* They pay careful attention to the actual path taken, as this is crucial to scoring well. It is also crucial to distinguishing *distance* from *displacement* – the 'hidden' agenda *(integrated learning of science concepts and processes).* The activity includes a guided-discovery worksheet [below]. The questions were taken from the SPH3U course and require students to consider the forces causing changes in motion. For the grade 10 motion unit, questions 4 and 5 could be omitted, or replaced appropriately.

Guided-Discovery Activity: Car Bowling

Literacy[3] 1 2 3 4 • Understanding 1 2 3 4

• Overall L-Score ____/5

1. How did today's activity differentiate between the terms *distance* and *displacement*?

2. Would the term *uniform velocity* (aka *uniform motion*) be appropriate to describe your car's motion across the table? Explain.

3. How does the term average velocity, v_{av} defined as $\Delta d / \Delta t$, apply to the motion of your car across the tabletop? Do you think it is an accurate representation of the entire trip?

4. Describe the motion of the car at the moment you released your car from rest. Then, the moment it struck the bowling pin. Speculate as to the causes of the change in motion.

5. Speculate as to how the motion of the car striking the pin might change if the plastic bowling pin was made of solid wood instead of hollow plastic. Explain your reasoning.

Coaching students to produce a detailed, grammatically correct report requires persistence and patience. To this end, they must be guided specifically as to what to write about, evidenced in questions 1-3 of the worksheet. Questions 4-5 allow for speculation and serve as a diagnostic about forces before this topic is introduced. These questions serve to link previous (grade 10) learning and foreshadow future topics *(sequenced into the flow of instruction).* A quick perusal of student reports informs instructors of the extent to which deep understanding of basic concepts has occurred.

Students are encouraged to discuss in groups as they prepare their worksheets *(ongoing discussion and reflection)*. If activities are sequenced in the flow of instruction, there is little need to copy from others. As subject confidence and the level of technical writing improves, activities and questions can become more comprehensive and integrative. It is not, however, a rapid process. Moving from *declarative* knowledge to *operative* knowledge is a route seldom traveled by students. Integrative thinkers enjoy the challenge while rote learners can find it stressful. It is a journey, with you as the guide. But if the grail we seek is improved understanding and higher-order-thinking, it must become our quest.

A highly effective technique for advancing technical writing skills is to collect some sample responses from student reports (do not include names) and have them assess [levels 1-4] the answers on the following criteria: i) does it answer the question asked, ii) is it correct, iii) is it complete, iv) is it grammatically sound. Level 4 responses can be copied and displayed as exemplars.

I think I can, I think I can

Highly effective laboratory experiences do not require onerous adaptations to teaching but do require methods different from our typical teacher-centred university experiences. This makes it challenging to perceive benefits of proposed changes or to imagine how your classroom should look and feel. I urge readers to take small risks and not expect the risks to immediately show results. Like all journeys, it is one small step after the other.

I would also urge readers to attend a workshop where these techniques are incorporated. Incorporated, not merely discussed or explained! Participation is key, as the comments of a leading PER researcher attest, *"Teachers should be given the opportunity to learn the content they will be expected to teach in the manner they will be expected to teach."* [4] Take advantages of opportunities in STAO, OAPT or other conferences. Scan the wealth of literature on the Internet (start with the PhET site mentioned earlier, then check out some of the links).

In future articles, we will examine how simple, highly effective laboratory experiences can repair student misconceptions and guide them to deeper understanding. The grail awaits.

References/Notes

1. *America's Lab Report: Investigations in High School Science* The National Academies Press, 500 Fifth Street, N.W., Washington, D.C. 20001, ISBN: 0309096715

2. "Reforming Physics Instruction Via Reformed Teaching Observation Protocol," Dan MacIsaac and Kathleen Falconer, Department of Physics SUNBuffalo State College, *The Physics Teacher* Vol. 40, November 2002.

3 I generally look for four elements when marking for literacy: i) does it answer the question asked, ii) is it correct, iii) is it complete, iv) is it grammatically sound. All four of these must be present in order to be level a L4. This is a useful - and simple criteria - which I have used from gr. 9 to 12. I develop exemplars early in the course, so this criteria is understood.

4. *Connecting Research in Physics Education with Teacher Education.* Lillian C. McDermott, Department of Physics, University of Washington, Seattle, Washington, U.S..A. An I.C.P.E. Book © International Commission on Physics Education 1997, 1998.